Electrocortical responses in reward paradigms and their variation related to personality

By

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Abstract

This thesis was conducted in order to investigate two issues: (1) how sensitive event related potentials (ERPs), and more specifically the medial frontal negativity and the P3 components, are to the valence and magnitude of reward-related stimuli, and (2) whether individual differences have an effect on the sensitivity of these ERP components to these characteristics. This was investigated using two reward-related paradigms.

In the "pure gambling task" participants were asked to choose between two cards, each containing varying dollar amounts (large or small). The outcome of the choice (i.e., win or loss) was revealed after the choice was made. Additionally, participants were shown whether the non-chosen card would have been a win or a loss. In the "simple response task", participants were presented with five cues (large win, large loss, small win, small loss or zero) that labelled the trial as either a potential win, a potential loss or no change. Following the cue, a target appeared on the screen and the participant's task was to press the response key while the target was still visible. A success led to a win (gain in money) or no loss (no change) depending on the cue. Thirty participants completed both tasks; afterwards they filled out a set of questionnaires measuring personality and other individual differences relating to risk-taking behaviour.

The results of both tasks showed that ERP components can differentiate between the valence and magnitude of reward-related stimuli, although no single component was uniquely related to either of the characteristics as previous suggested in the literature. Additionally, the context of the stimulus presentation (e.g., the task structure, condition within the task) affected the relationships between the ERP components and stimulus characteristics.

The relations among differences across participants in the ERP components and personality characteristics were inconsistent and, thus, no firm conclusions could be drawn. However, it must be noted that some of the relations were consistent within the tasks but not between tasks, suggesting that these are also affected by the context of the stimulus, potentially due to the role of individual differences on the psychological set at the moment of the stimulus presentation. The implications of these results for understanding the cognitive electrophysiology of reward processing are discussed.

In summary, results of the current thesis suggest that the task structure and goals determine the meaning of the stimulus to an individual, leading to specific psychological sets. Any relations observed between ERP components, their sensitivity to the stimulus and individual differences are moderated by these psychological sets.

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Rewards provide motivation for both simple and complex behaviours, such as seeking food or striving for academic success. Oftentimes the pursuit of the reward involves risky behaviour. For example, gambling is associated with the possible risk of losing money and smoking is linked to serious health risks. Nevertheless, people engage in these activities daily and with considerable differences in their definition of acceptable risks. In order to understand what factors contribute to these differences in behaviour we must first understand how reward-related behaviour arises.

There are several processes that are important for risk-taking or reward-related behaviour. Once the stimulus is presented, the organism is expected to engage in assessment of the value of the stimulus (i.e., forms a subjective value) based on the evaluation of the current needs and the required costs and efforts involve in obtaining the reward. Additionally, the individual should assess the risks associated with the attainment of the reward. The assessment of the risks involved is also subjective because it depends on previous experiences, estimations of probabilities of favourable outcome as well as inherent biases that an individual has (e.g., individuals high in harm-avoidance will be biased toward avoiding unfavourable outcomes and thus might overestimate the risks). Thus, reward-related behaviour depends on a number of factors governed by the neural circuitry, and consequently individual differences.

In the current thesis, reward processes associated with risk-taking behaviour are examined using event-related potentials (ERPs) and their relationships with a number of individual differences. Identifying ERP components sensitive to various characteristics of reward-related stimuli provides a time-sensitive, portable, and relatively inexpensive technique for the investigation of the impact of developmental and personality factors on each stage of the reward-related behaviour.

Reward-related neural circuitry

Reward-related behaviour includes assessment and assignment of a subjective value to the reward, and then regulation of behaviour accordingly. The *subjective* value of a reward will depend on the organism's internal state (e.g., if one is hungry, food will have a higher reward value than if one is satiated) and the amount of *risk* associated with obtaining the reward. In other words, the subjective value of the reward will affect one's motivation and consequently behaviour. This is achieved through recruitment of a number of subcortical and cortical structures (Rolls, 2005) mediated by several neurotransmitters (Gray & McNaughton, 2000). For simplicity, this review will be focused on the neurotransmitter dopamine and a few critical structures that have been shown to be most critically involved in reward-related behaviour.

Dopamine is a neurotransmitter most commonly associated with rewarding behaviour and is also well known for its role in movement control and in executive cognitive functions (see Schultz, 2007 for a review). Dopaminergic functions are determined by the region of activation as well as the mechanism of its release. Neurons originating in the substantia-nigra and projecting to the basal ganglia are responsible for movement regulation, while cells in the midbrain (ventral tegmentum) projecting to the limbic system and frontal cortex are associated with reward processing (Julien, 2005). This latter pathway, referred to as mesolimbocortical, projects to nucleus accumbens (NAcc), amygdala, and the prefrontal cortex (PFC). To date a number of studies have demonstrated involvement of these structures in reward-related behaviour (see O'Doherty, 2004, for a review).

The amygdala and NAcc have been shown to be active in response to obtaining a reward (Ernst et al., 2005). Another fMRI study showed significant activation of NAcc to both anticipation and acquisition of the reward (Dillon et al., 2008). However, an interesting finding by Wakabayashi, Fields, and Nicola (2004) suggests that NAcc does not play a direct role in the willingness of an animal to wait for a reward. Thus, while NAcc might be sensitive to anticipation and consumption of the reward, it is not required for reward anticipation once reward-seeking behaviour has been initiated.

More recently Kable and Glimcher (2007) demonstrated increased activity in the medial PFC and ventral striatum in response to increasing subjective values of rewards as measured by the delay discounting paradigm. In this paradigm, participants are presented with a number of monetary choices, where one can receive a small reward immediately or a larger reward after a certain period of time. The sizes of the reward as well as the delay periods were varied from trial to trial. Medial PFC has also been shown to be sensitive to the objective values of rewards (Potts, Martin, Burton & Montague, 2006).

Other structures directly involved in processing of rewards are dorsal striatum and PFC. Delgado, Locke, Stenger and Fiez (2003) have shown, using a gambling paradigm, that dorsal striatum is sensitive to the valence of the stimulus independent of its magnitude. However, the results showed that in the 6- to 9-second period after the presentation of the feedback, this area was also sensitive to the magnitude of the reward with largest rewards eliciting the highest BOLD response and large punishments the lowest. As for the PFC, more specifically orbitofrontal cortex (OFC), a number of studies have implicated this area as one that is sensitive to rewards (see Kringelbach & Rolls, 2004, for a review). For example, Kheramin and colleagues (2004) conducted an experiment in order to determine if rats with lesions to the dopaminergic afferent connections with OFC would behave differently from controls when given a choice between immediate and delayed rewards. The authors found that the lesioned group was less willing to delay gratification (i.e, had steeper slope of the discounting function),but were more tolerant of the delay to the large reinforcers (i.e., showed significantly longer indifference delays to the large reinforcers when compared to the sham lesioned group).,. However, it must be noted that higher tolerance for delays for large rewards does not indicate a steeper rate of discounting because the hyperbolic model of delay discounting is dependent on both the delay and the sensitivity to the reinforcer. In general, the results showed that these connections are important for the processing of both the reward size as well as to the delay of the reward.

Further support for the involvement of dopamine in reward-related behaviour comes from a study examining the effects of a dopamine agonist used to treat patients with Parkinson's disease (Dodd et al., 2005). The authors showed that higher doses of the drug can lead to maladaptive reward seeking behaviour such as gambling or excessive eating. They also noted that the more extreme cases of maladaptive behaviour were associated with a drug targeting D_3 receptors, which are present primarily in the phylogenetically older structures of the brain, including the limbic system. This finding further implicates the involvement of the mesolimbocortical pathway in reward-related behaviour.

Thus, the mesolimbocortical pathway is responsive to rewards and their anticipation. However, dopaminergic neurons also project to the area responsible for regulation of behaviour; namely the OFC, which includes the ventromedial PFC (vmPFC; Naqvi, Tranel & Bechara, 2004). As a part of the PFC, the OFC has also been shown to be sensitive to rewards among various sensory modalities, subjective measures (e.g., preference ranking) as well as abstract rewards (O'Doherty & Dolan, 2006). This sensitivity to various types of rewards as well as its connection to areas responsible for higher cognitive functions provides OFC with the necessary information to 'decide' on the appropriate behaviour. In fact, this area has been implicated in decision making due to its role in processing of emotional valences and adapting to changes in reward contingencies by inhibiting conflicting, irrelevant or competing behavioural responses (Bechara, Damasio, Damasio, & Lee, 1999; Katkin, Wiens & Ohman, 2001). People with lesions to OFC are characterized by behavioural disinhibition (Spinella & Miley, 2004; Chan et al., 2005), impulsivity, and lack of concern with negative consequences (Spinella & Miley, 2004). O'Doherty's (2004) review of experimental and lesion data further supports the involvement of OFC in behaviour regulation and, consequently, the decision-making process.

In summary, the subjective/motivational values of the reward are determined by the internal state of the organism. Further, the ability to code the reward value and adjust behaviour accordingly is primarily provided by the mesolimbocortical dopaminergic pathway. Thus, the subcortical and cortical areas that play a role in the reward-related behaviours are differentially involved during various stages of processing of this information. The numerous connections between these areas lead to relatively fast changes in the mesocorticolimbic pathway in response to changes at different stages of the behaviour.

ERP components in reward-related tasks

The rapid time-course of the events described above as well as the differential involvement of various cortical areas make ERPs an excellent method for tracking the changes in neural responses during the decision-making process. ERP components that differentiate between the stages of reward-related behaviour provide markers based on activity in the neural pathway and have been frequently used in research as a tool for investigation of reward-related processes. Localization techniques that have been developed for the ERP data allow researchers to associate activations of specific brain areas with the occurrence of any given ERP component. In this section, several studies investigating the sensitivity of ERP components to magnitude and valence of the stimulus, the most important of which is the feedback-related negativity (FRN) observed about 200-300 ms following feedback, are summarized.

Yeung and Sanfey (2004) showed that feedback of positive and negative valence elicits different amplitudes of FRNs. More specifically, losses on a gambling task were shown to elicit more negative (i.e., larger) FRNs than wins. This general result has been replicated a number of times since then using similar tasks (Toyomaki & Murohashi, 2005a; Goyer, Woldorff, & Huettel, 2008; Kamarajan, et al., 2009) and even without participants' active involvement (i.e., watched the choices of another; Yeung, Holroyd, & Cohen, 2005). Furthermore, Yeung and Sanfey (2004) reported that the P3 amplitude (a larger positivity observed 300-500 ms following the stimulus) differentiated between the magnitude of the reward but not the valence. However, the studies replicating the FRN results have shown that the P3 is sensitive to both magnitude and valence of the feedback (Toyomaki & Murohashi, 2005a; Goyer, et al., 2008; Kamarajan, et al., 2009).

Nevertheless, in most of the more recent work, researchers have concentrated on the FRN component in a quest to identify the extent to which it is sensitive to feedback characteristics as well as it's significance in reward processing. Holroyd and Coles (2002) proposed a reinforcement-learning theory that states that the FRN (as a component related to error-related negativity) is elicited when there is a mismatch between the expected and actual outcomes in a discriminant learning task and serves a signal for behavioural adjustments. Furthermore, they also proposed a neural mechanism for this action where FRN is a signal that is related to the anterior cingulate cortex (ACC) through the mesencephalic dopaminergic system.

The above theory was met with wide interest and support, which led to a number of studies investigating the sensitivity of FRN to predicted outcomes. For example, the FRN was found to be of similar magnitude for 'loss' and 'even' feedback in a gambling paradigm (Hajcak, Moser, Holroyd, & Simons, 2006). This finding suggests that the FRN is sensitive to the distinctions between favourable and unfavourable outcomes rather than other specific characteristics of the feedback. Furthermore, a series of experiments has consistently shown that negative feedback elicited larger FRNs than positive feedback (Holroyd, Hajcak, & Larsen, 2006). The neutral stimuli, once again, elicited FRNs of similar, if not greater, amplitude to negative feedback, thus suggesting that these two types of stimuli are treated similarly. The authors conclude that FRN categorizes feedback into two groups, achieving and failing to achieve the task goal, rather than processing the specific feedback given and thus is modulated by the context of the stimulus.

Another theoretical framework is that the FRN represents a warning of the potential for negative outcome rather than the outcome itself. Bellebaum and Daum (2008) showed that FRN magnitude of non-rewards and rewards were similar to the magnitude of negative prediction errors, such that FRN amplitude was larger for the unexpected negative outcomes. These results replicated a previous study, which also found that FRN was sensitive to violation of reward predictions (Hajcak, Moser, Holroyd, & Simons, 2007). However, in a recent study using a to-bet/not-to-bet paradigm, the FRN was found to be larger for the 'to bet' choices when compared to 'not to bet' as well as more negative (i.e., larger) for higher wagers (Yu & Zhou, 2009). It must be noted that some studies refer to this negativity as feedback related ERN, others as FRN or medial frontal negativity (MFN; e.g., Goyer, et al., 2008). MFN is a more encompassing term, as it can be applied to any negativity occurring over the medial prefrontal are of the scalp.

In summary, the FRN and the P3 ERP components were found to be sensitive to various characteristics of reward-related feedback. While the specific significance of this FRN sensitivity and the exact dimension of feedback differentiated are still debated, these components have proven useful in identifying participants' responses to feedback in general. Furthermore, the neural generators for the FRN have been localized to the ACC (Nieuwenhuis, Slagter, von Geusau, Heslenfeld, & Holroyd, 2005), which is interconnected with the OFC and other motivational and reward relate areas.

However, apart from differentiating between the valence and magnitude of feedback, individuals may interpret this feedback differently due to a number of other factors commonly referred to as personality or temperament variables. In order to understand reward and risk-related behaviour, these differences need to be accounted for because the biological bases of personality or temperament overlap with the reward-related circuitry (Gray, 1970; Gray & McNaughton, 2000; Haier, 2004; Schweighofer et al., 2009). Furthermore, personality traits have been shown to be related to various ERP components (e.g., Boksem, Tops, Kostermans, & De Cremer, 2008). The next section describes the primary personality traits related to reward-related behaviour as well as providing examples of integration of ERP components with investigations of the effect of personality on processing of information.

Individual differences in reward-related behaviour

Personality and other individual differences are often found to modulate ERP components (e.g., Pailing & Segalowitz, 2004; Boksem et al., 2006) and thus need to be considered when investigating the sensitivity of ERP components to various properties of stimuli. Furthermore, as discussed later in this section, individual differences and personality variables have been linked to neurobiological systems, providing additional reasons to consideration of these factors in investigation of ERP components. Several such differences are discussed below in the context of risk-taking and gambling behaviour.

One of the most influential theories of the neurobiology of personality was proposed by Jeffery Gray (see, for example, Gray, 1970). His model of a behavioural inhibition system (BIS) and behavioural approach system (BAS) accounts for behaviour through the action of two opposing neural systems. As summarized by Fowles (2006), the BIS responds to punishment, non-reward, and novelty by increasing arousal levels. It was originally proposed to involve the septohippocampal system and its projections to the frontal lobe. The theory of the septohippocampal system's involvement was based on the results of studies with anxiety reducing drugs (Gray & McNaughton, 2000). However, more recently, the authors have shown that these drugs have an effect on a number of pathways, consequently implying that the BIS is widely distributed over several neural pathways. Gray and McNaughton (2000) also indicate that both NAcc and amygdala have been implicated in the BIS neural pathways. However, the BIS pathways are thought to be regulated by other monoaminergic neurotransmitters, such as serotonin, rather than dopamine (Carver & White, 1994).

In contrast to the BIS, the BAS is responsible for activation of goal-directed or reward motivated behaviour (Carver & White, 1994). This system is thought to rely on mesolimbocortical dopaminergic projections (Fowles, 2006), which are sensitive to rewards. Carver and White (1994) developed the BIS/BAS scale in which BAS is measured using three different subscales: reward responsiveness, drive, and fun seeking. Individuals high on these scales seem to be relatively more motivated by rewarding stimuli. Consequently, these individuals should also be more sensitive to rewards, or willing to take higher risks to achieve smaller reward due to a relatively lower sensitivity to punishment and thus underestimation of the risks than individuals high on BIS.

Although there are a number of researchers investigating the relationship between ERP components and BIS/BAS scores, not all of these studies include reward-related tasks. For example, Boksem and colleagues (2006) investigated the relationship between the error-related negativity (ERN) and positivity (Pe) elicited in a standard flanker task (a perceptually based selective attention task) and BIS/BAS. The results showed that BIS was related to larger ERN amplitude, whereas BAS was associated with larger Pe amplitude. These findings were further supported by significant partial correlations between BIS and ERN, controlling for BAS and Pe and vice versa. The authors also reported that there were no significant correlations between BAS and ERN or BIS and Pe, thus showing double dissociation. These results suggest that BIS and BAS may reflect the activation of different neural processes, which then are responsible for producing distinct ERP components.

Recently it was shown that the amount of risk-taking in a gambling paradigm is governed more by the concerns for loss, as measured by the BIS sub-scale of the questionnaire, and not by the desire to win, measured by the BAS sub-scale (Demaree, DeDonno, Burns & Everhart, 2008). The authors of this study also found that sensation seeking was related more to the chosen probability of wins rather than the size of the wager. Additionally, research has shown that people who score high on sensation seeking also show higher activations of posterior medial OFC in response to emotionally arousing stimuli (Joseph et al, 2009). In an unrelated study, individual's level of risk-taking could be predicted from pre-task or baseline activations of the right PFC (Gianotti et al., 2009). Furthermore, predisposition to the sensation seeking behaviour is associated with higher risks of engaging in problem gambling (Johansson et al., 2009). Taken together, these findings suggest that high sensation seeking is related to higher activations of PFC, which then mediates the processing of the valence of the rewards.

Whereas predominance of the BAS and sensation seeking seem to predispose the organism to risk-taking, predominance of the BIS is thought to do the opposite. Additionally, BIS is thought to be activated in individuals who also have high levels of harm avoidance (Hansenne et al., 2003). Harm avoidance has been previously linked to ERP components by the same authors, but there has been little research done investigating the role of this trait in gambling paradigms, as well as sensitivity to reward magnitude and valence.

Another trait that might be relevant to performance on a risk-taking task as well as to a predisposition to reward-processing is impulsivity. One of the operational definitions of impulsivity is the preference of smaller immediate rewards over larger delayed ones or the inability to "delay gratification" (Evenden, 1999; Spinella, 2004). It has been proposed that individuals internally discount the value of the delayed reward (i.e., the longer one waits for the reward, the smaller is its perceived value); the more impulsive the person is, the higher is the discounting rate (Reynolds & Schiffbauer, 2004). This phenomenon is referred to as delayed discounting and has been demonstrated in a number of studies. Among those shown to have significantly higher discounting rates than the control populations are children with ADHD (Reynolds & Schiffbauer, 2004), drug users (Kirby, Petry, & Bickel, 1999; Epstein et al., 2003) and smokers (Ohmura, Takahashi, & Kitamura, 2005).

Most delay discounting tasks are concerned with monetary rewards and require one to choose between immediate and delayed monetary rewards. These tasks are proposed to measure impulsivity shown during decision-making (Reynolds, Ortengren, Richards & De Wit, 2006; Lagorio & Madden, 2005). As mentioned previously, OFC is involved in the evaluation of rewards as well as inhibition of impulses, which makes it a good candidate to be intimately associated with delay discounting. Consistent with this is Goldstein and colleagues' (2007) recent finding of a graded activation in the PFC of normal individuals as a response to increasing monetary rewards. However, this pattern of activation was not observed in cocaine addicts, the majority of which also rated $10 as being equally valuable, subjectively, as $1000. Additionally, Bechara, Tranel and Damasio (2000) also showed that patients with lesions to the vmPFC tend to strongly discount future consequences of their decisions.

Another set of individual differences that is relevant to reward-related and, more specifically, risk-taking behaviour is the degree of cognitive distortions that individuals engage in. The most common of these distortions are the illusion of control and gambler's fallacy (Steenbergh, Meyers, May & Whelan, 2002). Illusion of control refers to the belief that one's behavior influences the outcomes of a chance-determined event. Gamblers' fallacy, on the other hand, is one's belief that future chance outcomes are dependent on past chance outcomes. Individuals who hold these cognitive distortions are thought to be less cognitively sophisticated about the laws of chance and hence are more likely to engage in gambling behaviour (Johansson, et al., 2009). Both of these variables have been identified as risk factors for problem gambling (Johansson, et al., 2009) and thus are good candidates for individual differences that affect reward-related processing.

Furthermore, pathological gamblers also show higher levels of obsessive compulsive traits but not obsessive-compulsive disorder (Durdle, Gorey, & Stewart, 2008; Johansson et al., 2009), thus suggesting that this trait also has a role in reward related processing. However, there has been no research done investigating the impact of obsessive compulsive traits on ERP components in gambling or risk-taking paradigms. Similarly, Brand and Altstötter-Gleich (2008) have found that performance on the Iowa Gambling Task was related to certain characteristics of perfectionism (concern over mistakes and personal standards) but not related to perfectionism as a whole. The authors concluded that this trait can play a role in decision making but does not influence decisions made when the outcomes are uncertain. Similar to the literature on problem gambling and obsessive compulsiveness, the presence of these traits is related to risk-taking behaviour to some degree. Furthermore, Bagby and colleagues (2007) found that problem gamblers scored higher on neuroticism and lower on conscientiousness when compared to non-problem gamblers. This suggests that a number of individual differences and personality variables play a role in determining behaviour in risk-taking/reward-related situations but more research is needed to further clarify the relationships among these factors and ERP components, especially in the context of a risk-taking paradigms.

In summary, personality characteristics have been implicated in the processing of reward and risk-related information. However, there is still very little research exploring the relationships among the personality traits related to reward processing and the ERP components. Whereas some authors suggest that personality characteristics induce automatic biases in processing of information (e.g., Hansenne et al., 2003) or ,conversely, automatic biases in the processing of information might underlie the development of various personality characteristics, little work has been done to investigate the relationships between the ERP components and these characteristics in a task that would maximize the effect of these variables by utilizing relevant situations. Examining the relationships among the ERPs and these individual differences in a risk-taking or reward-related paradigm will allow for interpretation of the relationships in context of task goals and individual's decisions/behaviour providing a more comprehensive picture of the associations. In other words,varying the nature of the gambling task will provide a range of contexts in which to examine the ERP components and individual differences as well as the relationships among them.

Goals for this thesis

In this thesis two tasks, adapted from previous literature (Yeung & Sanfey, 2004; Bjork et al., 2004) were used in order to explore the sensitivity of ERP components to various characteristics of the stimulus and its context as well as relationships between these components and individual differences. More specifically, the ERP components' sensitivity to the valence and the magnitude of the stimulus in the context of feedback and potential reward/punishment were examined. Apart from investigating the effects of reward related individual differences discussed above (e.g., BIS/BAS, harm avoidance, cognitive distortions), the following studies also included a measure of sensitivity to reward and punishment, as these two scales are often thought to be related to the BIS/BAS measure [although a more recent study suggests that this relationship might not be as strong as previously suggested (Cogswell, Alloy, van Dulmen, & Fresco2006)].

It was expected that ERP components would differentiate between magnitude and valence of the stimuli. More specifically, the FRN component was expected to differentiate between wins and losses and the P3 component between large and small wagers, replicating Yeung and Sanfey's (2004) findings. Additionally, given the exploratory nature of the effect of individual differences on the ERP components, our hypothesis are tentative. Participants scoring high on behavioural inhibition (high BIS scores), harm avoidance and sensitivity to punishment were expected to react more strongly to losses and make fewer high-risk choices. Thus, it was hypothesized that these participants would have a stronger response to losses, which would be indicated by a larger FRN amplitude. Those with high BAS scores who also would score high on sensation seeking and sensitivity to reward were hypothesised to engage in riskier behaviour and have a relationship with ERP components complementary to the previous group of variables, i.e., to react more strongly to wins and to make more high-risk choices. Taking into consideration Yeung and Sanfey's (2004) findings, it is expected that these participants will show a smaller FRN in response to wins when compared to those scoring low on these measures. Furthermore, those sensitive to reward and high scores on BAS scale were also expected to differentiate more between rewards of various magnitude (large vs. small), as would be shown by a larger difference in P3 amplitude between the conditions.

Furthermore, higher levels of cognitive distortion and delay discounting scores were expected to be associated with riskier choices. Individuals high on cognitive distortions were also expected to have weaker reactions to losses (i.e., smaller FRNs). Measures of conscientiousness, neuroticism, perfectionism and obsessive compulsiveness traits were also included in the analysis as these characteristics were found to be potential risk or protective factors in pathological gambling. The relationships between ERP components as well as behavioural measures on the reward-related tasks were examined, but this investigation is exploratory and no specific hypotheses were made.

Study 1: Pure Gambling Task

As described earlier, Yeung and Sanfey (2004) investigated the sensitivity of ERP components to the magnitude and valence of rewarding stimuli. In their task, participants were asked to make a choice between two colour coded cards. Two of the four colours indicated large wager amounts and two were associated with small amounts. Participants were informed that either card could be a win or a loss and the results of their choice as well as the actual magnitude of the card would be revealed after the choice was made. Following the feedback on the chosen card, participants were also shown the alternative card. In examining the ERP components elicited by the feedback on the chosen card, Yeung and Sanfey (2004) found that the FRN component was sensitive to the valence of the feedback, such that FRNs to losses were more negative than to wins, but not to the magnitude of the chosen card. In contrast, the P3 component was sensitive only to the magnitude of the card, with smaller amounts eliciting a smaller P3 amplitude, but not to the valence of the feedback (Yeung & Sanfey, 2004). Thus, the authors concluded that valence and magnitude of reward-related feedback is coded independently in the brain and can be differentiated by specific ERP components.

Apart from investigating the ERP components to the chosen card, the authors also looked at the brain responses elicited by the alternative card. The ERPs did not dissociate magnitude and valence of the alternative card as clearly as in the case of chosen card: the P3 was sensitive to both magnitude and valence of the alternative, where as the FRN did not differentiate either. Following this, the alternative cards were grouped into two conditions: alternative worse than the outcome and alternative better than the outcome.

Once again, the FRN did not differentiate between the two conditions, whereas the P3 was larger when the alternative was better than the chosen card.

A modified version of the Yeung and Sanfey's (2004) task was used to further investigate the sensitivity of each component to reward magnitude and valence. Based on Yeung and Sanfey (2004), it was expected that the FRN component will be sensitive to the valence of the feedback and the P3 to the magnitude of the chosen card. Unlike the original task, the participants were shown the amount that could be won or lost prior to making a choice. This was done in order to ensure that the P3 component is sensitive to the magnitude of the stimulus in the context of the feedback. Furthermore, personality traits associated with reward-related behaviour (e.g., sensitivity to reward, harm avoidance) were measured so that they could be related to each ERP component.

Methods

Participants

Thirty-one Brock University students (*M* age = 22, *SD* = 2.82; 18 females) participated in this study during spring and fall semesters. All of the participants reported having no neurological conditions (e.g., epilepsy) or psychiatric difficulties (e.g., depression) that could affect the recordings and reported having normal or corrected to normal vision. The majority of the sample was currently completing an undergraduate degree (*N* = 23) and the rest was either in graduate school (*N* = 4) or were beginning employment (*N* = 4). Two people identified themselves as smokers. Nearly half of the sample did not gamble at all (*N* = 14) and, of those who did, seven spend between $3 and $5 a month on gambling and another 10 spend anywhere from $10 to $80. Overall, of those who reported engaging in gambling activities, 15% (*SD* = 26.4), with a minimum of 0.75% and maximum of 100% of total spending income was used for gambling.

Materials

The Task

The pure gambling task used in this study was adapted from Yeung and Sanfey's work in 2004 (see Figure 2.1). Participants were first presented with two cards, each showing the amount for a potential win or loss. The cards stayed on the screen until the participant made a choice and there were three possible combinations: cards with values that were both high, both low, or with one high and one low. The large amounts ranged from \$1.95 to \$2.05, while the small amounts were between \$0.45 and \$0.55. Once the choice was made, the chosen card was highlighted by a yellow border for 500 ms following which a plus or a minus sign, signifying a win or a loss respectively, appeared next to the amount. After an additional 1000 ms the card that was not chosen was highlighted by a blue border for 750 ms, after which a plus or a minus sign appeared next to the amount and stayed on the screen for 1000 ms. The win to loss ratio in the task was set to be 60:40. There was an equal number of win/win (i.e., chosen card was a win and the alternative outcome was also a win) and win/loss trials as well as an equal number of loss/win and loss/loss trials. There were 64 trials in each block, with an intertrial interval of 1000 ms, and 5 blocks in the entire task. At the end of each block the running total was shown and the participants could take a break of any desired length. At the end of the task participants were given the amount they won (M = \$8.29, SD = 12.98, minimum = -14.60, maximum = 28.52); however, it must be noted that the running total could go below zero and some participants failed to win anything on this task.

Individual Differences Questionnaires

Handedness Questionnaire. This measure was adapted from Oldfeild (1971) and assesses the degree of right/left handedness by asking participants to answer 10 questions about hand preference in various situations, e.g., Which hand is used to draw? Participants are asked to answer on a 6-point scale ranging from 1 (always left) to 6 (always right) to be recorded for demographic reasons (Appendix A).

BIS/BAS. Behaviour Inhibition and Behavioural Activation Scale were assessed using Carver and White's (1994) BIS/BAS questionnaire. It consists of 20 items such as 'I crave excitement and new sensations.' and participants will be asked to rate how accurately each item describes them on a scale ranging from 0 (very accurate) to 4 (very inaccurate; Appendix A).

Harm avoidance. This trait was measured using the harm-avoidance scale of the Temperament and Character inventory (Cloninger, Przybeck, Svrakic, & Wetzel, 1994). This questionnaire consists of 10 statements like 'I seek danger' and 'I know no limits'. The participants are asked to judge how well each statement describes them on a 5-point Likert scale, ranging from very inaccurate (1) to very accurate (5; Appendix A).

Sensitivity to reward/punishment. In the Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ; Torrubia, Avila, Molto, & Caseras, 2001), participants are asked to read 47 questions (e.g., Do you often refrain from doing something because you are afraid of it being illegal?) and decide which of the 4 choices most accurately describe them. The choices range from YY (very much yes) to NN (very much no; Appendix A).

Sensation seeking. This trait is assessed using Zuckerman's Sensation Seeking Scale (Zyckerman, Eysenck & Eysenck, 1978). The scale consists of 40 items (e.g., I prefer friends who are excitingly unpredictable) and participants were asked how much the agree or disagree with each statement on a four point scale with choice ranging from TT (very much true) to FF (very much false; Appendix A).

Perfectionism. The AB5C perfectionism scale (Hofstee, de Raad & Goldberg, 1992) consists of nine items and asks participants to rate the degree to which they agree with the statement on a 5 point Likert scale. The scale includes items such as 'I continue until everything is perfect' and 'I want everything to be "just right"' (Appendix A).

Neuroticism. The Neuroticism scale from the Abridged Big Five-dimensional Circumplex model (AB5C; Hofstee, de Raad & Goldberg, 1992) consists of 20 items (10 reversed keyed) and was obtained from the IPIP database. Participants are asked to rate on a 5 point Likert scale to what extend each of the statements (e.g., Often feel blue) describe them (Appendix A).

Conscientiousness. Similar to the neuroticism and perfectionism assessment the AB5C (Hofstee, de Raad & Goldberg, 1992), the conscientiousness scale consists of 20 items (e.g., Pay attention to detail) and asks participants to rate on a 5-point Likert scale how accurate each statement is in relation to their personality (Appendix A).

Obsessive-compulsive traits. The Obsessive-Compulsive Inventory Revised (OCI-R; Foa, et al., 2002) inventory consists of 18 items (e.g., I check things more often than necessary) followed by a 5-point scale on which participants indicate how distressed or bothered they were during the past month; Appendix A).

Gamblers' Beliefs Questionnaire. This scale is a self-report measure of gamblers' cognitive distortions (Steenbergh et al., 2002). The measure consists of two related factors: Luck/Perseverance and Illusion of Control. Participants are asked to rate on a 7-point Likert scale, where 1 corresponds to *strongly agree* and 7 to *strongly disagree*, the extent to which they agree with given statements (e.g., I have a "lucky" technique that I use when I gamble). The questionnaire was adjusted in order to be applicable to participants without prior gambling experience (Appendix A).

Delay discounting. This measure was developed by Kirby and colleagues (1999) and asks participants to circle one of two choices pertaining to the amount of money they would prefer from the options given (e.g., $25 today or $30 in 80 days?). In total the task has 27 questions. Based on the responses, the researcher can estimate the delay discounting rate for each of the participants, measuring the degree of impulsivity (Appendix A).

Procedure

After signing the consent form (Appendix B) and filling out the handedness questionnaire, participants were shown to the electroencephalogram (EEG) equipment and fitted with a 128-channel Hydrocel Geodesic Sensor (Electrical Geodesic, Inc., Eugene, Oregon) net. Participants were then asked to complete two tasks: a simple response task (see Study 2 for details) and the pure gambling task. Once the tasks were completed, participants were presented with 10 questions (see Appendix C) on the computer screen about their level of happiness or disappointment in each of the conditions (e.g., win/lose). Following the questions, the Sensor net was taken off and participants were given time to wash and dry their hair as well as take a break. When they were comfortable, participants were given a questionnaire package to complete at their own pace. Finally, the payment and the debriefing form (Appendix D) were given and the purpose of the study was explained.

EEG recording and analyses

EEG was recorded with 128 channels referenced to the vertex (Cz) using NetStation (Version 10.3). The signal was amplified by Net Amps 200 with a band pass filter of 0.01 to 100 Hz. The sampling rate was 500 points per second and the impedances were maintained below 50 kΩ. Once the recoding was completed it was exported from NetStation to Brain Vision Analyzer (Version 1.05) for further analyses.

Data from the bad channels (labelled as such after visual inspection of the raw data) were interpolated[1]; the data were re-referenced to a common average and filtered using a low pass filter of 30 Hz and high-pass filter of 1 Hz. Following this, segmentation was done. Feedback trials were segmented as a function of the chosen magnitude (large/small) and sign (plus/minus indicating win/loss). Each epoch ranged from 200 ms prior to the onset of the stimulus (used to calculate baseline) to 1000 ms after the stimulus. Analyses of the alternative card used the same length epoch and the segments were divided based on the comparison with the chosen card: win-joy if the chosen card was a win and the alternative card was worse (i.e., the chosen card had a better outcome than the alternative), or loss-regret if the chosen card was a loss and the alternative card would have been a better choice.

After segmentation of the data, ocular corrections were performed using the procedure of Gratton, Coles and Donchin (1983). Additionally, artifact corrections were done automatically, such that the amplitude was kept between -100 μV and 100 μV, and the maximal absolute difference of two values in the segment allowed was 150 μV. The averaged segments were scored for three components using ERPScore (Segalowitz,

[1] Note: On average two to four channels were interpolated per person, with maximum of six for one of the participants.

1999): P2 (positivity between 150 and 250 ms), feedback-related negativity (FRN; 200 – 350 ms) and P3 (300-500ms). Only the midline channels were scored (Fz, FCz, Cz, CPz). The amplitude, measured as base-to-peak (baseline was calculate using the data 200 ms prior to the onset of stimulus), and latencies for each condition and component were analyzed in SPSS 16.0. Within-subject ANOVAs were conducted in order to investigate the effect of magnitude and valence on the event-related potentials (ERPs). Additionally, correlations were carried out to examine the relationships between ERP components for various conditions and personality traits.

Results

Preliminary analysis of ERP components revealed that two of the participants were outliers (+3SD) on most of the ERP amplitude variables and thus their data were removed from further analysis. Without the outliers the distributions for all the components did not depart from normality (as tested by the Shapiro-Wilk test) and the skewness and kurtosis values were within the acceptable range (±1). Sensitivity to punishment scores were not normally distributed so the examination of all the relationships between this variable and ERP components used Kandell's tau coefficients. Furthermore, participants 14 and 20 were responsible for the relationships produced with the delay discounting and BAS scales, respectively, and therefore were also removed when examining relationships between ERP components and these variables. It must be noted that these participants were outliers (i.e., ±3 SD) on one of the scales (participant 14 on the delay discounting and participant 20 on the BAS), but not on any other variables.

Validity Checks

The task. The self-report of happiness for winning or disappointment for losing each amount was examined using repeated measures t-tests. Results showed that participants were more disappointed when they lost a large amount in comparison to losing a smaller amount, $t\ (29) = 14.27, p < .001$. Similarly, their self-reported level of happiness was higher in response to winning a large versus a small amount, $t\ (29) = 10.02, p < .001$. These results suggested that participants were engaging in the task as expected; reporting higher levels of disappointment when losing large amounts and higher levels of happiness when winning large amounts. Furthermore, participants reported no significant difference in the amount of happiness and disappointment when the alternative was, respectively, worse or better than the outcome, $t\ (29) = 0.52, p = .611$.

Furthermore, relationships between number of low and high choices on the high/low trials with personality measures were examined. There were no significant correlations with the majority of personality variables; however, the frequency of self-reported gambling behaviour was significantly negatively related to the number of low and positively to the number of high cards chosen. Participants who reported engaging in gambling behaviour (i.e., excluding those who did not) chose high value cards more often, $r = .53, p = .030$.

Individual Differences. Prior to investigating the relationships between ERP components and individual differences, several correlations were done to examine the relationships between the personality variables. More specifically, correlations were done to examine if BAS, sensation seeking and sensitivity to reward were measuring similar types of variance. There was significant positive relationships between BAS and sensitivity to reward, $r = .47, p =.013$, but not with sensation seeking, $r = .35, p =.071$; however, the latter was in the expected direction (i.e., positive). Sensitivity to reward was also positively correlated with sensation seeking, $r = .41, p =.039$. The relationships between BIS, harm avoidance and sensitivity to punishment were examined similarly. Scores obtained on the BIS were positively correlated with those of harm avoidance, $r = .41, p = .023$, and sensitivity to punishment, $r = .51, p = .003$. However, sensitivity to punishment and harm avoidance were not significantly correlated, $r = .29, p =.108$.

Behavioural Data

The summary behavioural data is shown in Table 2.1. Participants took longer to choose a low value card on the high/low trials than on the low/low trials, $t\,(31) = 4.13, p <.001$; however, choosing the high value card on high/low trials took as long as making a response on the high/high trials, $t(31) = 0.31, p =.757$. There was a significant difference in response times (RT) when choosing on high/high versus low/low trials, $t\,(31) = 3.89, p <.001$, such that it took longer for participants to choose the high card, but there was no difference in RT when choosing high or low card on the high/low trial, $t\,(31) = 0.52, p = .608$. In summary, choosing a high card took significantly longer compared to choosing a low card only when participants did not have any other option (i.e., comparing high/high trials to low/low trials). Choosing a low card, on the other hand, took longer in the high/low trials when compared to no other option trial (i.e., low/low). For graphical representation of these data see Figure 2.2.

ERP Data

Feedback on the chosen card. Prior to statistically examining the relationships between various trials and ERP components the stimulus-locked overlay of waveforms for this condition (Figure 2.3) was examined. A clear separation between win and loss trials started at the P2 component and continued to be present for the FRN was observed. Additionally, the low value wins for the FRN component seemed to be attenuated compared to those for the high value wins. The magnitude and valence did not appear to be associated with specific ERP components, as previously expected. The FRN appears to differentiate the valence of the feedback at specific sites as well as differentiate between the magnitudes of the wager on the win trials. The P3 component seemed to be differentiating between wins and losses at Fz, but between the feedback for large and small wagers at the more posterior channels. In order to examine these patterns quantitatively a 2 (valence) x 2 (magnitude) x 4 (site) repeated measures ANOVAs were conducted[2].

The ANOVA for the FRN amplitude showed a main effect of magnitude, F (1,28) = 27.86, $p < .001$, $p\eta^2 = .50$, valence, F (1,28) = 9.08, $p = .005$, $p\eta^2 = .25$, and site, F (3,84) = 29.38, $p < .001$, $p\eta^2 = .42$, $\varepsilon = 0.45$, as well as magnitude by site interaction, F (3,84) = 4.56, $p = .016$, $p\eta^2 = .14$, $\varepsilon = .73$. Additionally, there was a marginally significant magnitude by valence interaction, F (1,28) = 3.76, $p = .063$, $p\eta^2 = .12$ (see Table 2. 2 for means and *SD*s). The 2 (valence) x 2 (magnitude) repeated measures ANOVAs were conducted for each site in order to further investigate the observed effects. There was a significant main effect of valence such that FRNs for losses were consistently more negative that wins (see Figure 2.4 for the topographical map of the difference in FRN amplitude between the conditions). The main effect of magnitude was observed only at FCz, Cz and PCz, with feedback for small wagers eliciting larger FRNs than those

[2] Note. If the assumptions of sphericity were violated original degrees of freedom, Greenhouse-Geisser epsilon (ε) and the corrected p-value are reported.

observed after large wagers (Table 2.3). However, there was an interaction between valence and magnitude of the feedback at FCz, whereby the magnitude of the feedback was differentiated only during winning trials (i.e., low value wins produced larger FRN than high wins, $F\,(1,28) = 5.59, p = .025$, but there was no significant difference between wagers during loss trials, $F\,(1,28) = 0.41, p = .529$). Thus, in this study FRN was found to be statistically sensitive to both magnitude and valence of feedback. While losses and feedback for large wagers produced the largest FRN amplitude, the effect of magnitude at more anterior channels was observed only on the win trials.

Similar to the FRN results the 2 x 2 x 4 repeated measures ANOVA for the P3 amplitude showed a main effect of magnitude, $F\,(1,28) = 95.77, p = .023, p\eta^2 = .17$, valence, $F\,(1,28) = 25.64, p < .001, p\eta^2 = .48$ and site, $F\,(1,28) = 44.38, p < .001, p\eta^2 = .61, \varepsilon = .54$. Furthermore, there was a significant interaction between magnitude and site, $F\,(1,28) = 9.84, p < .001, p\eta^2 = .26, \varepsilon = .56$, as well as valence and site, $F\,(1,28) = 8.29, p = .001, p\eta^2 = .23, \varepsilon = .50$. Averages and standard deviations for the P3 amplitude at each site can be seen in Table 2.4. These relationships were further investigated by conducting 2 (valence) x 2 (magnitude) repeated measures ANOVA for each site (Table 2.5). As expected from the examination of the overlay the P3 component was sensitive to the valence of the feedback, but only at more anterior sites (i.e., Fz and FCz), such that losses elicited larger P3 amplitude (see Figure 2.4). The topographical maps showed that losses elicited more anterior P3, whereas the activation observed after wins was slightly more posterior (Figure 2.5). The main effect of magnitude was observed at FCz, Cz and CPz, with feedback for larger wagers eliciting a larger P3 amplitude (see Figure 2.6 for topographical representations). Thus, contrary to the expectations, the P3 component was sensitive to both the valence and the magnitude of the feedback, depending on the site examined.

In summary, both the FRN and the P3 components were shown to differentiate between the valence of the feedback as well as the magnitude of the wager; however, these effects were dependent on the site examined. The progression of sensitivity of the P3 component across sites, from magnitude at more posterior sites to valence at more anterior ones, suggests that different dipoles might be responsible for this differentiation, with the intermediate channel (FCz) measuring the overlapping signals.

Alternative outcome. Prior to statistical examination of the data, the stimulus-locked grand average of ERP components were visually examined in two overlays: Figure 2.7 shows alternative feedback of the four basic types (large/small loss and large/small win), and Figure 2.8 shows win-joy (alternative worse than outcome after win feedback) and loss-regret (alternative better than outcome on loss conditions). As can be seen in Figure 2.7, the ERPs four basic conditions were clearly separating at midline channels, with the exception of Fz. The FRN was separated on the basis of large versus small value alternative cards, without taking into account the valence of the card. The P3 component, on the other hand, distinguished between all four types of cards, with large loss cards eliciting the largest P3 amplitude and small win cards the smallest, as expected from previous literature. In figure 2.8, the overlay of joy versus regret showed a larger general positivity starting at the P2 component and continuing to P3 for the regret condition.

In order to statistically test the relationships for the FRN observed in the overlay, and due to great variations in the FRN size and amplitude (relative to baseline) between the channels four 2 (valence) x 2 (magnitude) repeated measures ANOVAs were conducted, one for each of the channels (Table 2.6; see Table 2.7 for the means and *SD*s). There were main effects of magnitude at FCz, Cz, and CPz, such that high value cards produced smaller FRN amplitude. There were no other main effects or interaction at any of the channels. Thus, the FRN was found to be sensitive to the magnitude of the alternative card but not its valence.

Similar analysis was done to examine the sensitivity of the P3 component to magnitude and valence of the alternative cards (see Table 2.8 for means and *SD*s). The P3 was found to differentiate between valence and magnitude of the alternative card (Table 2.9). However the 2 (valence) x 2 (magnitude) repeated measures ANOVAs also showed significant interactions at the majority of the midline channels (see Table 2.9). This effect was stronger at the more posterior channels (FCz, Cz, and CPz). Graphical representation of the data (Figure 2.7) showed larger differentiations between high and low cards when the card was also labelled as a win. This was supported by follow-up repeated measures ANOVA conducted comparing high and low cards for wins and losses at FCz, Cz, and PCz (Table 2. 10), showing that the effect of magnitude was stronger for the winning cards. Thus, P3 amplitude can be used to differentiate between magnitude and valence of the alternative card, with the largest amplitude for large wins.

Individual Differences

The scatter plots for the significant relationships between ERP components and measures of individual differences can be seen in Figures 2.9 through 2.37.

Feedback on the chosen card. The relationship between personality variables and ERP components were examined at limited sites to reduce Type I error. Cz was chosen for the FRN component due to its sensitivity to both magnitude of the wager and valence of the feedback, as well as its consistent use in previous literature (e.g., Boksem et al., 2006; Table 2.11). Cz was also chosen for examination of role of individual differences on the P3 amplitude for similar reasons. However, the relationships between P3 amplitude and personality were also examined at Fz due to the unique effects of valence observed at this channel. The results of the P3 analysis can be seen in Tables 2.12 and 2.13.

Contrary to expectations there were no significant relationships between BIS, harm avoidance and sensitivity to punishment with FRN amplitude (see Table 2.11). All of the participants showed larger FRNs for losses; additionally, there was a significant negative correlation between sensation seeking and FRN amplitude for low loss trials, $r = -.43$, $p = .027$ (Figure 2.9), such that participants scoring high on the SS scale showed larger FRNs when receiving loss feedback for low wagers compared to those scoring low on SS. These participants also showed larger P3 amplitude at Fz during the small loss condition, $r = .47$, $p = .015$ (figure 2.10). Thus, it seems that people who are prone to sensation seeking also respond with greater intensity to loss feedback after a low wager.

Furthermore, participants scoring high on the neuroticism scale showed larger FRNs in response to win feedback on small wagers, $r = -.39$, $p = .038$ (Figure 2.11). These participants also showed smaller P3 amplitude to win feedback for both small, $r = -.43$, $p = .022$ (Figure 2.12), and large, $r = -.38$, $p = .047$ (Figure 2.13), wagers as well as to large losses, $r = -.38$, $p = .047$ (Figure 2.14). There were no other significant correlations between simple conditions (i.e., Small/Large Loss and Small/Large Win) and personality variables.

In order to further investigate the relationships among the personality variables and the amplitude of ERP components, the difference in amplitude between win and loss as well as high and low conditions were examined. To obtain the difference scores for the valence of the feedback, several variables were computed. First, to obtain a score for loss condition the amplitude for feedback on large and small wagers was averaged. This was done for each component at each channel. Secondly, scores for win conditions were obtained in similar manner: by averaging amplitude of a specific component obtained in response to feedback for large and small wagers. Finally, the loss scores were regressed out of the win scores, and the unstandarized residuals were used as the difference residual scores between win and loss conditions. A similar procedure was used in order to obtain difference residual scores between large and small wagers.

There was a significant correlation between the BIS scores and the residual scores for the FRN amplitude between large and small wagers, $r = -.39, p = .045$ (Figure 2.15). More specifically, participants high on BIS differentiated less between feedback for the large and small wagers. The opposite trend was observed for participants reporting more obsessive compulsive characteristics, $r = .40, p = .042$ (Figure 2.16), where a larger number of self-reported obsessive compulsive behaviours was associated with larger residual scores between feedback to large and small wagers for FRN amplitude. Furthermore, participants highly sensitive to reward showed larger residual scores for the FRN between win and loss feedback, $r = .39, p = .047$ (Figure 2.17).

Similar examination of differences in P3 amplitude at Fz revealed no significant correlations with any of the personality variables. However, participants scoring high on cognitive distortions had smaller residual scores between win and loss feedback as indicated by P3 amplitude at Cz, $r = -.392$, $p = .039$ (Figure 2.18). A similar trend was observed with participants reporting more obsessive compulsive characteristics, $r = -.429$, $p = .023$ (Figure 2.19). The opposite trend was seen in participants scoring high on the perfectionism scale, $r = .375$, $p = .045$ (Figure 2.20): reporting more perfectionism traits was associated with larger residuals between wins and losses at P3. Additionally, the percentage of spending money used for gambling was correlated with the ERP components. There was a significant correlation between this measure of real-life gambling and the P3 amplitude at Fz elicited by large wins, $r = .44$, $p = .025$ (Figure 2.21), such that larger P3s were observed in participants who spend more money gambling. These participants also differentiated more between wins and losses at Fz (P3), $r = .40$, $p = .042$ (Figure 2.22). However, it must be noted, and can be seen in the scatterplots, that both of relationships were driven by several people who gambled the most.

Alternative card feedback. The role of individual differences in processing of the magnitude and valence of the alternative card was examined at Cz for both the FRN and P3 amplitude (Table 2.14 and 2.15, respectively). Correlations were run for each of the four types of cards (i.e., large/small loss and large/small win) as well as for the combination of card based on the feedback received on the chosen card (i.e., lose regret and win joy).

The amplitude of FRN component at Cz correlated negatively with neuroticism when the alternative card was a large loss, $r = -.37$, $p = .050$ (Figure 2.23), or a small win, $r = -.44$, $p = .018$ (Figure 2.24). Participants scoring high on neuroticism showed larger FRN to the lose valence of large alternative card and win valence for small cards. On the other hand, those scoring high on the conscientiousness scale showed smaller FRN amplitude in response to low loss alternative cards, $r = .39$, $p = .043$ (Figure 2.25). Smaller FRN amplitude was also associated with a higher score on cognitive distortions if the alternative cards were revealed to be a low value wins, $r = .39$, $p = .040$ (Figure 2.26). These relationships were not observed for the P3 component, but there were significant positive relationships between scores on the obsessive compulsive characteristics scale and P3 amplitude for the winning cards of any magnitude. More specifically, reports of more obsessive compulsive characteristics were associated with larger P3 amplitude when the alternative card was revealed to be a win of either large, $r = .47$, $p = 012$ (Figure 2.27), or small, $r = .52$, $p = .004$ (Figure 2.28), value.

More conscientious participants showed a smaller FRN amplitude when the alternative card was a worse choice when compared to the chosen win card, $r = .39$, $p = .043$ (Figure 2.29). At the same time participants reporting more obsessive compulsive characteristics showed larger P3 amplitude to both win-joy, $r = .38$, $p = .049$ (Figure 2.30), and loss-regret conditions, $r = .44$, $p = .019$ (Figure 2.31). Thus, these participants appeared to attend more to the revelation of the alternative card, regardless of the outcome.

To clarify the above-mentioned relationships further, a number of correlations were conducted between personality measures and residual scores for the amplitude of ERP components in various conditions. The residual scores were calculated similarly to the feedback difference scores: regressing the amplitude of a specific component in one condition out of another and saving the residual. In order to compare the role of personality variables in the processing of the alternative card to the chosen card, several residual scores were obtained: win versus loss, high versus low value, joy versus regret. Correlation coefficients obtained for the FRN and P3 components can be seen in Tables 2.16 and 2.17, respectively.

The results of the above analyses revealed that participants high on conscientiousness were also differentiating less between winning and losing alternative cards at the FRN amplitude, $r = -.40, p = .042$ (Figure 2.32). A similar relationship was observed between the residual scores for the P3 amplitude for winning and losing alternative cards and scores on obsessive compulsive scale, $r = .54, p = .003$ (Figure 2.33): reporting more obsessive compulsive characteristics was associated with smaller residual scores between two conditions. Similar to the results for the chosen card, those reporting higher levels of cognitive distortions also differentiated less between winning and losing cards as reflected in the residual scores of the P3 amplitude, $r = .43, p = .022$ (Figure 2.34). Participants that reported being sensitive to rewards showed larger differentiation between joy and regret conditions (i.e., between the alternative card being worse or better than the chosen one) as indicated by the larger residual scores of P3 amplitude, r = .43, $p = .027$ (Figure 2.35).

Relationships between a measure of real-life gambling and ERP components elicited by the feedback and alternative card were also investigated through correlations (Tables 2.18 and 2.19, respectively). Once again, these were driven by the several people that gambled the most. Spending more money gambling was associated with smaller P3 amplitude to large loss alternative cards, $r = -.48, p < .013$ (Figure 2.36) and showed larger FRNs to lose regret conditions, $r = -.42, p < .031$ (Figure 2.37).

Summary

Overall, the relationships between personality variables and ERP components for reward-related stimuli were found to be inconsistent and not as clear as expected; however, some trends could be observed. For example, participants reporting more cognitive distortions were found to distinguish less between win and loss feedback on the chosen card but showed larger differentiation with respect to the valence of the alternative card. Higher reports of obsessive compulsive characteristics were associated with smaller residual score for the magnitude of the chosen card. These participants also differentiated more between the valence of alternative card (i.e., winning cards vs. losing cards) and if choosing the alternative card would have been a better or worse decision (i.e., win joy vs. loss regret). On the whole, these participants seemed to respond more to the alternative card rather than the feedback on the chosen card.

One variable that stood out was the measure of sensitivity to reward. Participants who rated themselves as more sensitive to rewards also had larger residual scores between wins and losses on the chosen card and were more sensitive to the difference in the alternative card being a better versus worse decision (i.e., win joy vs. loss regret). Another variable that seemed to be associated with ERP components was neuroticism. Participants high on this trait showed smaller FRNs to low value wins and smaller P3s to wins in general. Additionally, these participants showed smaller FRNs to high loss and low win alternative cards. These relationships are not as easily interpretable as the ones summarized above and will require further investigation.

Discussion

This study was conducted in order to achieve two goals: (1) to determine if ERP components are sensitive to the valence and magnitude of rewarding stimuli replicating the previous work done by Yeung and Sanfey (2004), and (2) to investigate the role of individual differences in the processing of valence and magnitude of the presented stimuli following large and small wagers as well as in the evaluation of the decisions (i.e., was the alternative option a better or worse choice).

Valence and magnitude of the rewarding stimuli were found to be separable in the brain as the variance produced by each in the ERP components could be differentiated, but were not associated with specific ERP components. The valence of the feedback was differentiated by both FRN and P3 components, such that losses produced lager FRNs at all of the midline sites and larger P3 at Fz. Furthermore, positive and negative feedback for high wagers was associated with smaller FRNs and larger P3.

These results are somewhat consistent with the original literature indicating that valence and magnitude are processed separately in the brain; however, this separation did not translate into a double dissociation between ERP components and reward characteristics (Yeung & Sanfey, 2004; Goyer et al., 2008). The early processing of magnitude of the wager was also consistent with previous literature; however, the magnitude effects found in this study for the FRN were in the opposite direction to the previously reported ones (Goyer et al., 2008). It should be noted, however, that even though there was a statistically significant main effect of magnitude for the FRN, the ERP overlays showed that FRNs for low value losses were considerably smaller than those for high value wins, whereas low and high losses were of similar amplitude (see Figure 2.3). Thus, it is possible that the effect of magnitude observed in this study occurred due to the difference between high and low value wins rather than large and small wagers.

The examination of the valence and magnitude of the alternative card revealed larger FRNs for low value cards. The latter finding was consistent with Goyer et al.'s (2008) results. This reversal in FRN amplitude for the magnitude of obtained versus missed reward suggests that this component is sensitive to the context of the presentation of information and thus reflects evaluation of the stimulus in context rather than simply being a marker for magnitude processing. Holroyd, Larsen, and Cohen (2004) suggest that outcomes are determined along the dimensions of favourable/unfavourable such that the distinction between the two is apparent only after the alternative option is presented.

Holroyd and Coles (2002) suggest that the ACC generated negativity observed at the scalp is dopamine-mediated and reflects reinforcement learning. According to this theory the FRN in risk-taking tasks should reflect learning via comparison of expected to the obtained outcome and thus should be mediated by subject's expectations. In this case, FRN sensitivity to the magnitude of the stimulus should be mediated by the context of the stimulus presentation as well as subject's tendency to expect negative/positive outcomes.

Moser and Simon (2009) conducted a study examining the effect of win/lose expectations on the FRN magnitude in a guessing paradigm. Participants were asked to guess behind which one of the two doors was a 5 cent reward. A correct guess resulted in a reward, while after incorrect guesses participants did not earn or lose anything. Additionally, participants were asked to predict if they were correct or wrong before and after choosing the door. Their results showed that FRN was always larger to non-rewards than rewards. Its amplitude was further modulated by the expectations on the trial in which subjects were inconsistent in their predictions, such that FRN was largest when subjects initially expected to lose on the trial, but after choosing a door decided that they were going to win. Thus, last minute changes in expectations produced larger FRNs when compared to consistent trials (i.e., predicting and expected wins/losses before and after the choice).

The authors concluded that FRN reflects context-sensitive evaluation of behavior and therefore a larger need to adjust performance, as in the case of changing from the prediction from loss to more favorable expectation of win. The above described study supports the notion that FRN amplitude reflects expectations rather than processing of specific magnitude or valence of the stimulus. It is then not surprising that the effects of magnitude on FRN amplitude were modulated by the context of the card (i.e., chosen versus alternative option).

The effects found in this study for the P3 component were also not as clear as expected based on Yeung and Sanfey's (2004) work. The sensitivity of this component to magnitude and valence of feedback was found to depend on the site of examination. More specifically, this component was found to differentiate between losses and wins but only at Fz. Analysis of the P3 at Cz revealed only the main effect of magnitude, such that feedback to higher wagers elicited larger P3s. In previous studies, researchers investigating the sensitivity of ERP components to reward magnitude and valence have also reported that the P3 component is sensitive to both valence and magnitude of the reward (Toyomaki & Murohashi, 2005b). Nevertheless, the results suggest that valence and magnitude of reward related stimuli are processed separately in the brain.

It must be noted that when the P3 component was scored, no differentiation between P3a and P3b were made. Previous literature suggests that these two components are differentially affected by the complexity of the task, such that P3 amplitude at Pz decreases with task complexity whereas P3 at Fz increases overall (Segalowitz, Wintink, & Cudmore, 2001). The authors suggested that that the observed changes are due to reallocation of attentional resources from the stimulus processing to the 'attentional activities of the frontal lobe" (p.456, Segalowitz, Wintink, & Cudmore, 2001). In the current study, P3 at Fz was large for losses, which suggests that losses attracted more of the attentional resources requiring frontal lobe involvement than simple stimulus processing.

In conclusion, the results of this study did not replicate the clear dissociation of valence and magnitude of the feedback at the scalp found by Yeung and Sanfey (2004; i.e., specific ERP components), but do suggest that these two properties of the stimulus are processed separately in the brain. The data thus supports the separation of subjective value of the stimulus and prediction of potential outcome as separate stages in the risk-taking behaviour. The processing of the magnitude of the stimulus is reflected in both components, but for different reasons. If the FRN is an indicator of discrepancy between expected and obtained outcomes, then the magnitude of the stimulus can mediate the participant's expectations. For example, because choosing small amounts instead of large ones is generally considered a less risky decision, participants might expect a higher rate of positive outcome. Thus, losing on the low value trials would be the more unexpected outcome and thus would produce a larger FRN because in this task the positive and negative feedback was assigned randomly. In future studies, researchers should also measure participant's expectations for each trial and the discrepancy between the expected and obtained outcomes in order to examine this hypothesis further.

These expectations are further mediated by personality variables (e.g., sensation seeking). A sensation-seeking tendency is one of the risk factors for problematic gambling (see Johansson et al., 2009, for a review) and is often associated with more risky choices. Thus, choosing low cards on the task would be a more conservative choice, especially for those scoring high on sensation seeking scale. Receiving loss feedback on the low wagers was associated with larger FRN and P3 amplitude for sensation seekers. This could be a further indicator that FRN is mediated by expectations, such that participants that were making a more conservative choice, especially given their personality trait, would expect less to be penalized for it, thus eliciting larger FRN amplitude.

Another example of support for this theory about the FRN is provided by the relationships between amount of cognitive distortions endorsed by participants and the ERP amplitudes produced in response to the feedback on the chosen card and the opportunity to evaluate the decision made. Participants scoring high on the gambler's beliefs questionnaire showed smaller differentiation between win and loss feedback as measured by the FRN amplitude. Furthermore, these participants showed larger differentiation between the win and loss valences of the alternative card. Thus, not only do they process wins and losses on the chosen card similarly, more attention is paid to the not-chosen card.

The cognitive distortions measured by the questionnaire are illusions of control and emphasis on luck. One of the questions loading high on the luck subscale of the questionnaire is "when I am gambling "near misses"…remind me that if I keep playing I will win" (Steenbergh et al., 2002). This belief would be reinforced by the revelation of the ‘missed’ outcome and it is not surprising that these participants differentiated between ‘missed’ wins and losses more.

Apart from affecting participant’s expectations, sensation seeking and tendency for cognitive distortions have been identified as risk factors for problem gambling (Johansson et al., 2009). Similarly, these researches have also shown that a higher number of obsessive compulsive traits reported by participants are also associated with problem gambling (Johansson et al., 2009; Durdle, Gorey, & Stewart, 2008). Obsessive compulsive disorder is associated with hyperactivity of the OFC (see Fontaine, Mattei & Robert, 2007), area that is commonly implicated in reward processing and control of behaviour. Thus, maladaptive responses in risky but rewarding situations can be expected. The relationships among ERPs and the number of obsessive compulsive characteristics reported were similar to those between ERPs and cognitive distortions; participants that were endorsing more obsessive compulsive behaviours differentiated less between valence of the feedback for the chosen card and more between the alternative cards of different valences as shown by the residual scores using win and loss cards in each condition of the P3 amplitude.

The most adaptive responses were seen in participants scoring high on the sensitivity to reward scale. Higher sensitivity to reward was associated with larger differences between the valence of the chosen card as measured by the residual scores calculated for the FRN amplitude. Furthermore, when provided with an opportunity to evaluate their decision, these participants differentiated more between alternative cards that would have been better or worse choice. Thus, these participants used the opportunity to evaluate their decision and learn from both the outcome of their choice and the revelation of the alternative option. In fact, de Ruiter and collegues (2009) found that pathological gambling was related to reduced reward and punishment sensitivity induced by monetary gains and losses. This reduced sensitivity was indicated by hypoactivation of ventrolateral PFC. Their results provide further support to the advantage in gambling paradigms provided by higher sensitivity to reward, suggesting that sensitivity to reward can act as a protective factor; however, more research is needed to support this hypothesis.

In conclusion, the relationships between personality variables and ERP components in response to a gambling paradigm were not as clear had been predicted. However, the obtained results suggest that FRN amplitude is mediated by expectations and is a reflection of discrepancy between expected and obtained outcomes (e.g., making a more conservative choice but still losing). Furthermore, this paradigm was effective at eliciting ERPs that differentiated between valence and magnitude of the stimulus and the relationships observed between personality and ERP amplitude were consistent with literature on problem gambling.

Study 2: Simple Response Task

Recently there has been an increase in interest in investigating the neural correlates of reward-related behaviour, as well as the developmental factors that can influence such behaviour. The majority of research conducted in this area is focused on the sensitivity of ERP components to various characteristics of reward-related feedback: magnitude, valence as well as context of the stimulus. However, reward-related tasks present participants with more information than just the feedback regarding the performance on the task. For example, in the period between the response and the presentation of the feedback, participants are engaged in prediction or at least in anticipation of the outcome. The design of the task can lead to responses associated with reward-related stimuli, besides those related to the outcome of the trial. Furthermore, other factors, for example developmental factors and individual differences, can affect the brain responses to the reward-related stimuli. Whereas there is little research done investigating specific personality differences and reward-related brain responses, some researchers have looked at the role of developmental factors in processing of reward related information (e.g., Bjork et al, 2004, Galvan et al, 2006).

Bjork and colleagues (2004) used fMRI to investigate the difference between adults and adolescents in activation of NAcc and mPFC during a reward-related task. On each trial participants were shown a cue that labelled the trial as either a potential win, a potential loss, or no gain/no loss. There were five cues in total: large win/loss, small win/loss and no gain or loss. The task required participants to press a key in response to a target that appeared after the first cue. The duration of the target on the screen varied. Additionally, the time period between the first cue and the appearance of the target varied. This time was labelled the anticipation period. In order to gain a reward or avoid losing, the participants were required to press a key while the target was visible. If the response was too slow participants either gained nothing on the trial or lost a small/large amount depending on the type of trial. Activations of NAcc and mPFC during the anticipation and feedback periods were measured using fMRI.

The authors showed that during the anticipation on the win trials, the NAcc was more activated in both groups when compared to other types of trials; however, this activation was greater in adults than in adolescents. Once the feedback on the win trials was given, both groups showed NAcc and mPFC activation. The difference between the groups was found in response to loss cues and loss trials; during the anticipation period on the potential loss trials, adults showed deactivation of mPFC which was not observed in the adolescents. The same pattern emerged once the negative feedback (i.e., losing) was given. In other words, while adolescents showed similar activation of both NAcc and mPFC in response to rewarding stimuli, they did not process the negative consequences of the behaviour to the same extent as adults. Thus, developmental factors play a role in the anticipation of the outcome as well as evaluation of the behaviour. It is also possible that such factors also appear as individual differences (e.g., some young adults acting more like adults, others more like adolescents). One shortcoming of fMRI has been poor time resolution; thus, replicating the results with ERPs, a more time-sensitive technique, will provide a more detailed picture of the role such factors have on reward-related behaviour.

In the current study, a modifided version of the task was used to further investigate the sensitivity of the ERP components to valence and magnitude of the stimulus in a different context (when compared to Study 1). Unlike in the previous task, this one contains another condition with magnitude and valence information of the reward that is separate from the task goals (i.e., obtaining or not obtaining the reward). If the sensitivity of the ERP components to the valence/magnitude of the cue stimulus are similar to those elicited by the feedback of comparable valence/magnitude, it could be said that the characteristics of reward-related stimulus are processed equally regardless of the context of presentation (i.e., potential vs. obtained).

In the current study, we examined the P3 and FRN (or MFN) components of the ERP, in response to the different reward-related cues and feedback. Relationships between these components and a number of personality factors (e.g., harm avoidance, sensation seeking) will be investigated. It is expected that the FRN component will be sensitive to the valence of the feedback as well as the cues and the P3 component to the magnitude of the cues. Previous work has shown that these ERP components are sensitive to the magnitude and valence of the stimuli only in the context of feedback (Yeung & Sanfey, 2004).

Methods

Participants

The participants were the same as in Study 1 (see pg. 18 for details)

Materials

The Task

The Simple Response Task used in this study was adapted from Bjork et al. (2004) task (see Figure 3.1). Participants were first presented with a cue that labels the trial as a potential win or a loss. There were five types of cues: small win (+$0.50), small loss (-$0.50), large win (+$3.00), large loss (-$3.00) and zero ($0). For the first 15 participants, wins were presented in green and losses in red; the colors were reversed for the remainder of the participants. Each cue stayed on the screen for 500 ms. Following the cue was the anticipation period that was either 1sec, 1.5 sec or 2 sec in length. During the anticipation period participants saw a grey screen, without any fixation point. Prior to the start of the task, participants were told that a grey square with a picture of a green street light will appear on the screen after the cue. In order to win or avoid losing money the participants had to press a button on the response pad while the target was still on the screen. During the first trial the target stayed on the screen for 280 ms. If the participants responded within this time, on the next trial the target was visible for 10 ms less. On the other hand, if the participants' response was after the 280 ms period (i.e., after the disappearance of the target), an extra 20 ms was added to the target duration on the next trial. These corrections ensured that participants won approximately one third of the time, as well as corrected the difficulty of the task according to each person's response times.

The win or loss feedback was given to the participants 1000 ms after the disappearance of the target. Any trial where the response was made within the duration of the target was labelled as a win and any other or later response was labelled as a loss. The feedback stayed visible on the screen for 1000 ms, following which participants were shown their running total for another 1000 ms. The intertrial period was also 1000 ms. There were nine blocks of the task, with 45 trials in each, and the participants were given a break between each block. The length of the break was under the participants' control.

Prior to the beginning of the task, participants were told that the amount won during each block of the task (i.e., before each break) would be recorded. At the end of the session participants were presented with nine cards and were asked to draw a card.

Each card contained a number of a block (i.e., a number from one to nine). The amount of money that they had won in that block was the amount they were paid for this task. Participant's knowledge of this process ensured that effort and motivation was relatively equal in each of the blocks.

Personality measures

See study 1 for details (pg. 19).

Procedure

After signing the consent form and being shown around to the lab, participants were familiarized with the EEG recording equipment. After filling out the demographic and handedness questionnaire, each participant was fitted with a 128-channel Sensor Net. Participants were given the instructions for the simple response task and a chance to complete a 10 trial practice block. Upon the completion of the first task participants were given a longer break and were introduced to the pure gambling task (see Study 1 for details). Once the tasks were completed, the sensor net was taken off and participants were given a chance to wash up and take a break. The last stage of the session included filling out the questionnaire package, which participants completed once they felt comfortable. Finally, the payment and the debriefing form were given and the purpose of the study was explained.

EEG Recording and analysis

See study 1 (pg. 23) for details on the recording, data and analysis criteria. The segmentation and the processing of the data used the same criteria as in Study 1; however, in this case data were segmented for the presentation of the cue as well as the feedback. It must be noted that FRN refers to the negativity that follows the presentation of the feedback and thus is an inappropriate term to use for the component elicited by the presentation of the cue. Thus, in the latter condition a negativity that occurred 200 – 300 ms after the presentation of the cue is referred to as more general MFN component.

Results

Preliminary analysis of ERP components showed no outliers. Furthermore, the data were normally distributed for all components, with the exception of the MFN component for the small win measured at FCz, $W = 0.93, p = .048$. Additionally, the FRN amplitude for the win condition at CPz and loss condition at Cz was found to violate the assumption of normality, $W = 0.90, p = .008$ and $W = 0.91, p = .012$, respectively. Any relationships found with these variables should be interpreted with caution, especially the analysis with individual differences. The skewness and kurtosis for all of the ERP components were within the acceptable range (±1).

ERP Data

ERP amplitude to the cue. The stimulus-locked overlay of the averaged ERP for the five types of cues (Figure 3.2) showed a slight differentiation between large and small cues for the MFN at FCz. However, the magnitude and the valence of the cues were not consistently separated for any of the components. In order to examine this further, small and large cues were averaged in order to create win and loss groupings. An overlay of the averaged ERPs can be seen in Figure 3.3. This overlay showed a slight separation between wins and losses that started at the MFN component and continued to be seen at the P3, such that wins were more positive than losses. This separation was largest at about 500 ms after the presentation of the cue. Similar averaging was done in order to separate the cues based on the magnitude only (Figure 3.4). The MFN component in this case did not clearly dissociate large and small cues at any of the channels with the exception of FCz; however, large cues produced a larger P3 (i.e., more positive) amplitude. The zero cues seemed to be treated differently from any of the groupings (i.e., by magnitude or valence) and did not produce a clear FRN or P3.

A 2 (magnitude) x 2 (valence) x 4 (channel) repeated-measures ANOVA was conducted for the MFN and the P3 components in order to statistically examine the effects observed in the overlays (see Table 3.1). The assumptions of sphericity were violated and thus the values using the Greenhouse-Geisser correction were used in the analysis of both the MFN and P3 sensitivities (original degrees of freedom and Greenhouse-Geisser ε are reported). There was a main effect of magnitude, such that large values elicited a smaller MFN amplitude. Furthermore, there also was a main effect of valence, such that losses elicited a larger MFN amplitude. Additionally, there was a main effect of channel, such that the MFN amplitude was maximal at Fz and minimal at CPz (see Table 3.2). Furthermore, there was an interaction between magnitude and channel, as well as between magnitude, valence and channel. In order to examine these interactions further, a 2 (valence) x 2 (magnitude) repeated-measures ANOVAs were conducted for each channel (see Table 3.3)

There were main effects of magnitude at both Fz, and FCz, such that large cues elicited a large MFN amplitude; however, this effect was not observed at either Cz, or CPz. Similar patterns were observed for the valence of the cue, where losses were associated with larger MFN at Fz and FCz but not at Cz or CPz. However, there was an interaction between magnitude and valence that was observed only at Fz , F (1,29) = 5.98, p = .021. Losses and wins were differentiated by the MFN amplitude but only for the large cues, $t(29) = 3.80, p = .001$, and not the small ones, $t(30) = 0.42, p = .681$. Thus, it seems that MFN is sensitive to both the valence and the magnitude of the stimulus; however, the degree of this sensitivity varies with the site. Overall, larger MFNs were observed for the losses, as well as small cues, with the largest MFN elicited by small losses.

The overall ANOVA for the P3 amplitude (Table 3.4) did not show any main effects of magnitude, or valence. However, there was a main effect of site, where the maximal P3 amplitude was observed at CPz and the minimal at Fz. However, previous research (Yeung & Sanfey, 2004) examined the P3 sensitivity at Cz only, rather than across several sites and thus 2 x 2 ANOVAs for each site were conducted (Table 3.5). Once again, there were no main effects of either magnitude or valence at Fz, FCz or Cz. However, there was a main effect of valence at CPz, where the P3 amplitude was maximal, such that win cues elicited larger P3 amplitude when compared to losses.

In summary, the MFN component was shown to be sensitive to both the valence and the magnitude of the cues, such that largest MFN amplitude was elicited by small losses. The P3 component was not sensitive to the magnitude of the stimulus, but differentiated between wins and losses at CPz. The sensitivity of both components depended greatly on the site of examination.

ERP amplitude and latency for the feedback. Initially the feedback was segmented into four different conditions: win feedback on win cues (i.e., gaining money), win feedback on loss cues (i.e., no loss), loss feedback on win cues (i.e., no gain) and loss feedback on loss cues (i.e., lose money). The overlay of the averaged ERPs for the four segments was examined visually prior to statistical analysis (Figure 3.5). The ERPs for the loss feedback, for both win and loss cues grouped together and were associated with smaller FRNs and larger P3s when compared to the win feedback. Furthermore, the P3 for loss feedback seemed to peak later than the P3 elicited by the win feedback. Based on these observations the ERPs were averaged into two groups: loss (i.e., for win and lose cue trials) and win (i.e., for win and lose cue trials) feedback. The overlay for the two conditions can be seen in Figure 3.6. The FRN component was larger and peaked earlier for the win condition. A similar trend was observed with P3 component. To statistically examine these observations, four 2 (valence) x 4 (channel) repeated measures ANOVAs were conducted, examining the FRN and P3 sensitivities based on the amplitude as well as latency of each component. The Greenhouse-Geisser correction was used when sphericity assumptions were violated, original degrees of freedom as well as Greenhouse-Geisser ε were reported.

The FRN amplitude differentiated between loss and win feedback (Table 3.6), such that losses were associated with smaller FRN amplitude. Furthermore, there was a main effect of channel, such that the FRN amplitude was largest at FCz (Table 3.7). This more anterior effect can be clearly seen on a topographical map (Figure 3.7). The examination of the FRN latency revealed a main effect of valence (Table 3.8): the FRN on loss trials peaked later when compared to wins. There was also a main effect of site, and a trend for the interaction between valence and site. Overall, the FRN peaks at Fz and FCz occurred later than those at Cz and CPz (Table 3.9).

The 2 x 2 repeated measures ANOVA for the P3 amplitude showed no significant main effect of valence, (Table 3.10; Figure 3.8 for the grand average topographical representation). Similar to the FRN results, there was a main effect of site, such that the

P3 amplitude was maximal at Cz and minimal at Fz (Table 3.11). However, the latency of P3 differentiated between wins and losses (Table 3.12), such that P3 for losses peaked later than for wins (Table 3.13). There were no other significant effects.

In summary, the FRN differentiated between wins and losses, such that wins were associated with larger and earlier FRNs. The P3 component was not as sensitive as the FRN to the valence of the stimulus; only the latency differentiated between wins and losses, such that the P3 peaked earlier for the wins.

Individual Differences

As mentioned previously in Study 1, participants 14 and 20 were responsible for the relationships with delay discounting and BAS, respectively, and thus were removed from the analysis when examining the relationships between any of the ERP components and these variables. Furthermore, sensitivity to punishment scores were not normally distributed and thus the correlations with ERP components were done using Kendall's tau. The scatter plots for the ERP amplitudes and personality measures for the significant relationships can be seen in Figures 3.9 through 3.32.

ERP component elicited by the cue. The maximal amplitude of the FRN, observed at Fz, and P3, observed at CPz, were correlated with scores obtained on a number of individual differences questionnaires. The amplitude for each of the components was averaged in order to obtain four scores: large cue (averaging large wins and large losses), small cue, win cue (averaging small and large wins), loss cue. Following this, adjusted scores between the conditions (i.e., large vs. small and win vs. loss) were calculated by regressing one condition out of another (e.g., small was regressed out of large) and saving the residuals. The residuals were then correlated with the scores on personality measures in order to examine the effects various characteristics have on the degree of differentiation between the conditions.

There were no significant correlations between the ERP components for any condition an amount of money spent gambling (Table 3.14). The relationships between the ERP components and the residual scores can be seen in Table 3.15. Participants who reported having higher levels of cognitive distortions, $r = .49, p = .006$ (Figure 3.9), and conscientiousness, $r = .38, p = .045$ (Figure 3.10), differentiated more between large and small cues as measured by the MFN amplitudes. Similarly, those who scored high on the neuroticism scale showed less differentiation in the P3 component, between the magnitudes of the cues, $r = -.37, p = .045$ (Figure 3.11). Furthermore, participants with higher levels of obsessive-compulsive characteristics differentiated more, as measured by the MFN amplitude, between win and loss cues, $r = .37, p = .050$ (Figure 3.12). Similar relationship was observed between sensitivity to reward and difference scores for the P3 amplitude: participants who reported being more sensitive to reward differentiated less between cues of different valence, $r = -.42, p = .025$ (Figure 3.13). Thus, levels of cognitive distortions and conscientiousness are associated with processing of the magnitude of the cue. Additionally, obsessive-compulsive characteristics, sensitivity to reward and neuroticism play a role in processing of the valence of the cue.

Apart from relating to the residual scores, the measures of individual differences also were associated with the amplitude of ERP components elicited by the five types of cues. There were several significant correlations between the MFN amplitude at Fz and harm avoidance (Table 3.16). More specifically, participants scoring high on this scale showed smaller MFN amplitude to small wins, $r = .49, p = .006$ (Figure 3.14), small losses, $r = .43$, $p = .016$ (Figure 3.15) and larger wins, $r = .48$, $p = .007$ (Figure 3.16). Thus, higher levels of harm avoidance were, in general associated with smaller MFNs to the majority of the cues. Similarly, participants who score high on sensation seeking also show larger MFNs to several cues: small losses, $r = -.38$, $p = .044$ (Figure 3.17), and large wins, $r = -.45$, $p = .016$ (Figure 3.18). Smaller MFN amplitude was also associated with high scores on the measure of cognitive distortions on the large win trials, $r = .37$, $p = .045$ (Figure 3.19). In other words, smaller MFN amplitude was associated with greater harm avoidance, reduced sensation seeking and higher levels of cognitive distortions in response to cues of various magnitude and valence.

The examination of the relationships between personality and the P3 amplitude at CPz (Table 3.17) revealed that higher levels of harm avoidance were associated with smaller P3 amplitude for the small loss cues, $r = -.36$, $p = .049$ (Figure 3.20). However, those scoring high on sensation seeking showed larger P3 amplitude to this cue, $r = .39$, $p =.042$ (Figure 3.21). In general, higher levels of harm avoidance were associated with smaller amplitude of both P3 and MFN after the presentation of the cues. The relationship between the cues and sensation seeking is not as straightforward; the large loss cue elicited a larger ERP component for those high in these characteristics, while other cues were associated with smaller amplitudes.

There were several relationships between the personality characteristics and the zero cue for both MFN and P3 components (Table 3.18): high scores on the measure of cognitive distortions, $r = .43$, $p = .019$ (Figure 2.22), as well as higher levels of harm avoidance, $r = .44$, $p = .045$ (Figure 2.23), and perfectionism, $r = .36$, $p =.048$ (Figure 2.24), were associated with smaller MFN amplitude after the zero cue. These relationships were not seen with the P3 component; however, higher levels of BIS were associated with smaller P3 amplitude, $r = -.42, p = .020$ (Figure 2.25). Furthermore, higher levels of impulsivity, as measured by the delay discounting scale, were associated with larger P3 amplitude elicited by the zero cue, $r = .42, p = .028$ (Figure 2.26). To summarize, higher levels of harm avoidance, perfectionism, cognitive distortions and impulsivity as well as lower activity of BIS were associate with smaller amplitude of ERP components elicited by the zero cue trials.

In summary, the cue stimulus informed the participants about the potential outcomes of the trial (i.e., gain vs. loss). Participants who scored lower on the harm avoidance and cognitive distortions and scored higher on the sensation seeking scale showed larger amplitudes of the ERP components to the cues that signified potential gains. However, scoring high on sensation seeking and low on harm avoidance (but only in case of small losses) was associated with larger ERPs. Zero cues (i.e., no change) elicited smaller amplitude of ERP components for those who scored high on harm avoidance, perfectionism and cognitive distortions and low on the delay discounting scale. The magnitude of the cue was differentiated more by those with high levels of cognitive distortions and conscientiousness. Individuals with higher levels of obsessive compulsive characteristics and neuroticism, as well as lower levels of sensitivity to reward differentiated more between the cues of difference valence.

ERP components elicited by the feedback. The FRN amplitude observed after the feedback was maximal at Fz; however, the maximal P3 amplitude was observed at Cz. In order to be consistent with previous literature (e.g., Hajcak & Simons, 2002; Boksem et al., 2008) and reduce Type I error all of the correlations were done using the ERP amplitudes measured at Cz. The residual scores between win and loss feedback were calculated by regressing the ERP component's amplitude elicited by the wins out of the amplitude elicited by the losses. The saved residuals from each of the regressions were used as to indicate the degree of differentiation between the valence of the feedback (i.e., wins versus losses).

FRN amplitude was found to be correlated with harm avoidance and sensation seeking (see Table 3.19 for correlation coefficients for all the personality measures). More specifically, higher levels of harm avoidance were associated with smaller FRN amplitude for both wins, $r = .40$, $p = .028$ (Figure 3.27), and losses, $r = .42$, $p = .019$ (Figure 3.28), and sensation seekers showed larger FRNs after receiving win feedback, $r = -.40$, $p = .035$ (Figure 3.29). Similar examination of the relationships between the P3 amplitude and personality variables (Table 3.20) revealed a relationship with harm avoidance and sensitivity to reward. Higher levels of harm avoidance were associated with larger P3 amplitude for both wins, $r = .62$, $p = .001$ (Figure 3.30), and losses, $r = .36$, $p = .048$ (Figure 3.31). Participants who reported being sensitive to rewards showed larger P3 amplitude for losses, $r = .43$, $p = .021$ (Figure 3.32).

Summary. There were a number of relationships between the FRN and P3 components and personality variables. Harm avoidance was one of the personality traits that stood out more often. Specifically, participants who scored high on this trait showed smaller FRN amplitudes to all of the cues, except large loss, as well as both types of feedback. However, these participants showed larger P3 amplitudes to the feedback, in general. Thus, it seems that while the cues were not as important for these participants, they paid more attention to the feedback of any type.

Another measure that related to the P3 amplitude for both cues and feedback was the sensitivity to reward. Higher levels of reward sensitivity were associated with larger residual scores comparing cues of difference valence as well as larger responses to the loss feedback. Overall, these participants processed cues based on the valence and paid more attention to losses. Furthermore, sensations seekers showed larger FRNs to the cues signifying potential large wins as well as win feedback in general. It must be noted that the same participants also showed larger FRN and P3 amplitude to small loss cues. There were a number of other relationships between personality and ERP amplitude; however, none of the characteristics related to the components were elicited by both the cues and the feedback.

Discussion

Magnitude versus valence sensitivity of ERPs

Previous research (Yeung & Sanfey, 2004) suggested that magnitude and valence of reward-related feedback is processed separately in the brain and can be dissociated by two distinct ERP components: the FRN and P3. One of the goals of this study was to further investigate the separation of magnitude and valence of reward-related stimuli. Unlike in Yeung and Sanfey's (2004) work, the paradigm used in this study gave participants a sense of control over the outcomes. Furthermore, participants were presented with cues of various magnitude and valence, which allowed the examination of the sensitivity of the ERP components to the potential reward rather than the reward itself.

In general, it was found that both the P3 and the FRN component differentiated between the valence of the cue, where potential gains/wins were associated with smaller FRN and larger P3 amplitude. Larger FRN amplitude following a stimulus of negative valence is a well documented finding in the current literature; however, in most of the studies only the effect of feedback on the ERP amplitude was investigated (Toyomaki & Murohashi, 2005a; Yeung & Sanfey, 2004; Holroyd, Hajcak, & Larsen, 2006). Results from the current study suggest that stimuli that predict potential reward and those that inform of reward attainment (i.e., feedback) are treated similarly in the brain, such that valence and magnitude of the stimulus are separable. It must be noted, that similar to the pure gambling task larger amounts produced smaller FRN amplitudes. Additionally, as the magnitude and valence could be differentiated by the ERP components, further support for the dissociation of these characteristics of a reward was provided.

While the ERP sensitivity to the potential gains and losses was consistent with the literature, the relationships between these components and the type of feedback was more complicated. The FRN and the P3 amplitude did not differentiate between positive and negative valence of the feedback that was also associated with no monetary gains or losses (i.e., win on loss cues or lose on win cues). Previous research suggests that the FRN amplitude differentiates between outcomes that are generally positive or negative in nature (Hajcak, at al, 2006) rather than other characteristics of the feedback. Furthermore, Holroyd and colleagues (2006) suggest that the FRN categorizes the feedback not based on the valence (i.e., gaining or losing money) but rather in terms of whether participants succeed or fail to achieve the goal assigned by the task (e.g., responding within the allotted time). Following this logic, it is not surprising that the ERP components elicited by the feedback were based on the valence of the outcome regardless of the type of trial; however, this still does not explain why losses elicited a more positive waveforms.

The sensitivity of both P3 and the FRN components to the valence of the feedback were not surprising either, given the results of the pure gambling task as well as recent research on the separation of magnitude and valence of the rewards (Goyer et al., 2008; Kamarajan, et al., 2009). However, the direction of the relationships was an unexpected finding: losses were associated with smaller and later FRN peaks. Furthermore, the amplitude of the P3 did not differentiate between the two types of feedback but losses were found to peak later than wins. This suggests that in this task the MFN obtained after the presentation of the cues and the FRN following the feedback were governed by different stimulus characteristics, rather than the valence. Several studies have suggested that the FRN is sensitive to the salience of the stimulus (Nieuwenhuis, Yeung, Holroyd, Schurger & Cohen, 2004), task goals (Holroyd et al., 2006) as well as participant's predictions (Gehring & Willoughby, 2002). Thus, previous research suggests that FRN amplitude can be modulated by a number of factors, one of which is the valence of the stimulus. While there has been research examining the FRN amplitude in a passive gambling task (Yeung, Holroyd, & Cohen, 2005), there has been no research in the gambling literature examining the ERP sensitivity to characteristics of the feedback when participants are given a sense of control over the outcomes. These results provide further support for the sensitivity of the FRN component to the task goals and the context of the feedback. Further research will be needed in order to examine the relationship between the FRN sensitivity and the degree of perceived control over the outcome of the task.

Individual Differences and ERPs

Similar to the previous study, the amplitude of ERP components was further modulated by a number of individual differences. Levels of harm avoidance and sensation seeking were found to be related to the ERPs elicited by both the cue and the feedback. Nordin and Nylander (2007) found that pathological gamblers score high on harm avoidance as well as novelty seeking. The authors stated that the relationship with harm avoidance was not surprising, as this trait is often linked to patient groups. In the current study, participants scoring high on harm avoidance showed smaller FRN amplitude to all of the cues, except the large loss cues. While these participants process large loss cues similarly to other individuals, the difference between the responses elicited by these cues and other cues might indicate that more emphasis is placed on the worst outcomes. Thus, participants scoring high on harm avoidance process the worst outcome (i.e., large losses) in the same way as other participants, they discount the positive ones. This relationship is not counter-intuitive but would be considered maladaptive in a gambling situation, due to a bias toward one type of outcome, rather than the evaluation of all the possibilities.

As mentioned previously, sensation seeking was another trait that was associated with both responses to cues and to the feedback. More specifically, sensation seekers showed larger FRNs to small loss and large win cues, as well as larger P3 amplitude to small loss cues. The relationships observed between the FRN amplitude and this trait are hard to interpret, given the scarcity of research done on the relationship between ERPs elicited by rewarding stimuli and sensation seeking. Overall, it seems that sensation seekers find relatively risky situations engaging; however, at least in this population, they do process negative outcomes similar to other participants.

Another risk factor for pathological gambling is the number/levels of cognitive distortions related to gambling that one reports (Johansson et al., 2009). In the current study, cognitive distortions were associated with larger differentiation between the magnitude of the cue as well as smaller FRNs to large win and zero cues. The participants engaged more in the processing of the magnitude of the potential outcome rather than its valence. This suggests that participants with higher levels of cognitive distortions find the size of the potential outcome more important than its valence. The illusion of control as well as belief in luck are the two cognitive distortions measured by the gamble's beliefs questionnaire (Steenbergh et al., 2002). In real life situations, cognitive distortions give gamblers a false sense of control over the outcome. In real life situations the size of the wager is determined by the person's decision, which is further depended on the levels of confidence in the win, mediated by the level of cognitive distortions. In the case of this task, size of the wager was predetermined and thus the magnitude of the wager could, in turn, mediate one's confidence in positive outcome. However, future research, measuring participant's levels of confidence in positive outcome prior to the feedback or given the option "to place a bet" of their choice, is needed in order to support this hypothesis. Overall, there were a number of relationships with specific components of the task and personality traits. However, these relationships were hard to interpret given their specificity (e.g., relationship with only one type of cue and one component but not others), lack of literature investigating individual differences in reward-related tasks as well as the potential for Type I error. The role of each of the measured personality characteristics is further discussed in the next chapter, where the results obtained from the two studies are compared.

General Discussion

This thesis was done in order to examine if magnitude and valence of reward-related stimuli are processed separately in the brain, how sensitive the FRN and P3 components are to each of the characteristics, as well as the role that individual differences play in the processing of these characteristics. In Study 1, the pure gambling task was used to investigate the sensitivity of the ERP components to the outcome of a gamble as well as the alternative outcome. Participants were asked to choose between the two cards and had no control over the outcome. In Study 2, the simple response task participants were given a false sense of control over the outcome, where the win or loss on a trial depended on the participant's response times, but the task was adjusted to ensure a certain number of losses. ERP components to the stimuli representing potential gains or losses were examined in order to determine if the dissociation between the valence and magnitude of reward-related stimuli is specific to the feedback or to any reward-related information. Furthermore, similar ERP components elicited by the outcome of each trial were compared. This analysis allowed the comparison between the two tasks, and revealed the effect of task goals on the sensitivity of each component. The relationships between the above mentioned components and measures of individual differences were also examined.

Valence vs. Magnitude

In the beginning of this thesis reward-related behaviour was discussed in terms of several processes governed by neural circuitry as well as individual differences. The engagement of the organism in the assessment of the reward's value occurs directly after the presentation of a rewarding stimulus. Previous research implicates the NAcc (e.g., Ernst, et al., 2005), ACC and OFC/mPFC (e.g., Kable & Glimcher, 2007) areas as well as dopaminergic regulation of these areas in the processing of the reward value.

The reinforcement learning hypothesis suggests that the MFN component in various tasks, especially in the reward-related tasks, is produced by the modulation of dopamine levels in the ACC (Holroyd & Coles, 2002). However, recently there has been a debate about the sensitivity of this component to specific characteristics of the stimulus: some state that it is sensitive to the fulfillment of task goals (Holroyd, Hajcak, & Larsen, 2006), whereas others suggest it is modulated by the salience of the stimulus (Nieuwenhuis, et al., 2004). In light of the current findings, it can be argued that when the outcome is uncertain the MFN component is sensitive to the valence and magnitude of the stimulus rather than other characteristics (e.g., color, task goals). In Study 2, simple response task, when the initial cue was presented (labelling the trial as potential win/loss) participants did not know whether the task goals had been fulfilled and the stimuli did not differ on any other characteristics (e.g., color, size). Since the information given to the participants was reward-related, it is plausible to assume that information was coded via the manipulation of dopamine levels (Holroyd & Coles, 2002). Furthermore, the effects found for the potential gains/losses replicate those found for the actual outcomes (e.g., Goyer et al., 2008), which suggests that the MFN component observed after these stimuli is similar in nature, if not the same, as the FRN, further justifying the use of the more general term.

It must be noted, that when the results of the simple response task and the pure gambling task are considered together, the context sensitivity of the FRN/MFN became apparent. Whereas valence and magnitude accounted for different variance in the ERP components, suggesting the differentiation in the neural processes associated with these characteristics of the feedback, i.e., the FRN amplitude was larger for losses than for wins on the pure gambling task and vice versa on the simple response task. The results obtained in Study 2 (simple response task) were inconsistent with previous literature (Yueng & Sanfey, 2004) and those of Study 1.However, it must be noted that all of the tasks used in the other studies did not give participants a sense of control over the outcome. Thus, other factors, apart from the valence and magnitude of the outcome, can influence the amplitude and latency of ERP components' amplitude and latency. In fact, the effect of other factors (e.g., expectations) might overshadow the role of magnitude and valence of the outcome.

The activity observed at the scalp is a summation of the activity of several neural networks, each responsible for the processing of specific characteristics of the stimulus. After the evaluation of the value of the stimulus, the individual engages in the prediction of potential outcomes. Each process leads to an alteration of a psychological set and thus affects how further information is processed. Because this prediction and anticipation of the outcome occur after the evaluation of the stimulus, the psychological set of the participants at the moment of receiving feedback in Study 2 was different from that of Study 1. Consequently, the effect of these processes on the observed scalp activity might be stronger. In the pure gambling task the magnitude of the stimulus was known prior to the valence (i.e., if they would gain or lose money), but the valence was known after the prediction and anticipation of the outcome. In the simple response task, the valence and the magnitude of the stimulus were revealed prior to the response. Thus, the valence of the outcome was evaluated based on participants' expectations, rather than just the presented feedback. Combined with the sense of control over the outcome, the participants' expectations could have played the strongest role in the processing of the feedback, resulting in the observed differentiations in the ERP components. Although the two tasks present relatively similar information in terms of stimulus characteristics (i.e., valence, magnitude) the ordering of this information leads to different psychological sets at the moment of processing of feedback, thus, leading to the difference in observed ERP components.

The results of the two studies show that valence and magnitude of the outcome are not the only characteristics of the feedback that modulate the observed activity at the scalp. However, previous research shows that FRN amplitude is affected by the salience of the feedback (Nieuwenhuis, et al., 2004). Thus, it would appear that the dopaminergic system is sensitive to the valence of the feedback, but is further modulated by the magnitude of the win or loss. The present results suggest that factors such as the task goals, the salience of the stimulus as well as the expectations of individuals also influence the nature of the response. Little research, if any, has been done in order to investigate the relative importance of each of these factors when it comes to the modulation of specific ERP components associated with neural responses to winning or losing in games of chance

Further support for the importance of the above mentioned factors comes from the investigation of the ERP components elicited by the alternative outcome on the pure gambling task. In this case, FRNs were greater for smaller win/losses and P3 was greater for large wins. Furthermore, being informed that the alternative outcomes were better than the chosen ones produced larger FRNs and P3s. The latter finding provides more support for the effect of expectations on the amplitude of the ERP components (i.e., participants expect that the chosen card is a better option until proven otherwise). Based on these results, it can also be suggested that the loss/no gain outcome in the simple response task is a reflection of regret versus joy rather than the processing of the valence of the stimulus.

Overall, the influence of each step of the proposed model on the ERP components depended on the sequence of events of the task. For example, in the pure gambling task the sequence of presentation of information to the participants emphasized the valence of the feedback, as well as the evaluation of the chosen response. However, in the simple response task more emphasis was placed on the prediction and anticipation of the outcome, as the magnitude of the reward and the valence of the trial were known ahead of time. Thus, any model of reward-related behaviour will have to account for the differential responses associated with the sequence of presented information.

Role of Individual Differences and Personality

BIS/BAS and related personality measures

Previous research has shown that ERP components are modulated by individual differences in personality (Boksem, et al., 2008; Hansenne, et al., 2003; Hajcak & Simons, 2002). Although the BAS, sensitivity to reward and sensation seeking should be related, the correlations among these questionnaires, as observed in the current studies, suggest that sensation seeking and BAS measure separate constructs. The correlations with harm avoidance and sensitivity to punishment showed that both of these measures are positively related to BIS but not to each other. It must be noted that the limited number of participants included in this study could have reduced the power available to observe some of the expected relationships so that these findings will need to be replicated with a larger sample before any firm conclusions can be drawn.

The correlations with ERP components were not uniform enough to suggest a simple model. More specifically, the relationships observed between the personality measures and ERP components were inconsistent. While sensation seeking and sensitivity to reward were significantly correlated, there was no condition in any of the tasks where these measures related similarly to ERP components. In addition, neither BIS nor BAS consistently related to the ERP components. As described previously, the BIS is thought to be distributed over several neural networks and not just that of dopamine (Gray & McNaugton, 2000). Therefore, if MFNs reflect modulation specifically in the dopaminergic system, it is not surprising that BIS scores did not relate consistently to MFN components. However, the BAS was originally thought to be modulated by the dopaminergic system (Fowles, 2006), which is inconsistent with current findings. It is possible that effects of the BAS on ERPs are small and can be seen only when extreme groups are compared. Given that this sample did not contain a low BAS group (with lowest score being 25 out of 52), the effects of this measure might have been missed. Furthermore, the inconsistency of the relationships between the ERP components and individual differences suggest a large rate of Type I error and thus further replication is needed for distinctive conclusions.

Harm-avoidance was the only personality variable that related somewhat consistently to the ERP components, although only in Study 2 (simple response task). The effects of valence and magnitude of the stimulus seem to be modulated by one's level of harm avoidance. More specifically, participants scoring high on harm avoidance showed smaller MFNs in response to all type of cues (with the exception of the large loss cue) and win and loss feedback. However, the relationship between the valence of feedback and harm avoidance was seen only in the simple response task, which suggests that harm avoidance related to the MFN through modulation of individual expectations rather than the processing of the valence of the feedback itself.

The results obtained for the ERP components in the simple response task were in conflict with the previous literature, as losses elicited smaller FRN and larger P3 amplitude instead of the usual pattern, suggesting that task demands critically affect FRN and P3 amplitude. However, more research is needed in order to determine more precisely the exact characteristics of the task that modulate the FRN and P3 effects.

Measures of real-life gambling behaviour, impulsivity and cognitive distortions

The degree to which individuals spend money on gambling activities was utilized as a measure of real life gambling behaviour. Participants who spend more money on gambling showed a larger difference in FRN amplitude when comparing wins with losses in the pure gambling task (Study 1). However, there were no relationships between this measure and ERP components obtained in the simple response task. These results also provide further support for the hypothesis that the ERP components elicited by the feedback in the pure gambling task and in the simple response task are modulated differently. However, it must be noted that these relationships were driven by several individuals who gambled more than the rest of the sample. It is possible that participants who gamble more often are more sensitive to the difference in context of pure gambling versus what is seemingly a skill task (i.e., when outcome depends on the response time).

These relationships suggest that the pure gambling task is more representative of the real life gambling situations.

Participants' impulsivity in this study was defined as the inability to delay monetary rewards and was measured using a delay discounting task. There were no consistent relationships between this measure and the ERP components. Previous research showed that higher levels of delay discounting were associated with lower levels of serotonin (Schweighofer, et al., 2008). Thus, while gambling behaviour was found to be related to higher levels of impulsivity in an extreme group (Alessi & Petry, 2003), this relationship might not be as easily observed in reward-related tasks where the ERP components are thought to be modulated by the dopaminergic system.

Relationships between ERP components and measures of cognitive distortions were also inconsistent and thus should be interpreted with caution. In the pure gambling task (Study 1), the overall score on the cognitive distortion scale was associated with less differentiation between wins and losses as well as larger differentiation between the valences of the alternative card. Thus, it seems that this characteristic influences processing of the valence of the feedback but not valence of the stimulus in general. In the simple response task, higher levels of cognitive distortions were associated with a larger difference in FRN amplitude between large and small cues. Taken together, the results suggest that cognitive distortions interfere with the processing of the valence of the stimulus differentially depending on the context of the stimulus (e.g., feedback vs. alternative card/potential outcome). It is possible that participants with more cognitive distortions are more sensitive to the change in the psychological sets that occurs between the conditions. Once again, more research is needed to further investigate this issue.

Other personality measures

Another personality measure of interest was the level of obsessive-compulsive characteristics reported by the participants. Previous research shows that pathological gambling is associated with higher levels of the obsessive compulsive characteristics, but not with obsessive-compulsive disorder (Durdle et al., 2008). In Study 1 (pure gambling task) participants with more obsessive compulsive characteristics differentiated less between wins and losses, as measured by the residual scores of the P3 amplitude to wins corrected for losses, but showed larger differentiations between the valences of the alternative option measured by the residual scores for the P3. Thus, once again the effect of this variable on the sensitivity of the ERP components is modulated by the context of the stimulus.

The last set of personality traits of interest were neuroticism and conscientiousness. Previous research has shown that higher conscientiousness and lower neuroticism levels were associated with smaller changes in the ERN between different motivational conditions (Pailing & Segalowitz, 2004). In that study, the effects for conscientiousness disappeared after accounting for the effects of neuroticism. In the current studies, opposite effects were similarly shown for conscientiousness and neuroticism. Higher levels of conscientiousness were associated with larger residual scores between large and small cues in the simple response task. The opposite relationship was observed for the individuals scoring high on neuroticism (i.e., smaller residual scores between cues of different magnitude), although on a different component (FRN versus P3). Furthermore, higher levels of self-reported conscientiousness negatively correlated with the FRN amplitude to the small loss alternative card (in the pure gambling task), whereas all the correlations observed with neuroticism were in the opposite direction.

Summary

The relationships between ERP components and individual differences were inconsistent not only when compared between the tasks, but also between different conditions within the same task (e.g., cue vs. feedback in the simple response task). The observed inconsistencies also suggest that the ERP components are modulated by the individual differences only within specific contexts. If it was the case that a specific personality trait was associated with larger amplitude of a component, then this relationship would be observed regardless of the context of the stimulus eliciting the component, as it would be a stable trait. However, in both studies the observed relationships depended on the context of the stimulus. For example, relationships with harm avoidance were observed only in the simple response task, while those with neuroticism only in the pure gambling task. Thus, the results of the current studies suggest that the sensitivity of ERP components is modulated by the context, and that the relationships with individual differences are also subject to this modulation.

Conclusions

Researchers have recently turned to the investigation of risk-taking behaviour from social, developmental and neurobiological angles (e.g., Durdle et al., 2008; Galvan et al., 2006; Delgado et al, 2003). Whereas this research has shed light on a number of aspects of gambling behaviour, some questions are as yet unresolved including the issue of how sensitive ERP components are to processes that occur during risk-taking behaviour (e.g., processing of the outcomes)? Also virtually unstudied is the role individual differences play in these relationships and how they affect the risk-taking behaviour. In an attempt to answer these questions two gambling paradigms were employed. Our results indicate that the valence and magnitude are processed separately in the brain, as shown by the sensitivity of the ERP components to each of the characteristics without any consistent interactions. This conclusion is further supported by the effects of individual differences on each of the characteristics separately, i.e., the sensitivity of the ERP components to each is further modulated by individual differences. However, neither the valence nor the magnitude of the stimulus could be associated with a single specific ERP component. The correlations with individual differences varied depending on the context of the stimulus; this implies that the patterns observed at the scalp are context dependent and may reflect shifts in psychological sets.

Furthermore, the comparison between the tasks revealed that the ERP components are also sensitive to the task goals. In the simple response task the magnitude and the valence of the reward could be separated at the stage of the cue (i.e., potential outcome). However, the ERP components elicited by the actual outcome did not vary as a function of obtaining the money but rather as a function of meeting the task goals (i.e., responding fast enough). While the processing of the reward valence and magnitude can be separated, these effects are superceded by an interaction with the task goals. Thus, a study of ERP effects needs to carefully consider not only the type of feedback (valence and magnitude) but also the task design and instructions.

A number of factors involved in reward-related behaviour was proposed: subjective value of the reward, risks associated, predictions of the outcome. The results obtained in both studies suggest that the relative importance of the factors influencing the

ERP components depends on the task structure. The above-mentioned processes are involved in any risk-taking behaviour, where the outcomes are uncertain and the organism has to make a response. The majority of people are faced with similar decisions everyday but gambling represents a specific subset of these choices where individuals voluntarily put themselves in a risk-taking situation. From the results described above, one main conclusion can be drawn; individuals' reactions to a gambling situation are governed by the context of the behaviour, which in turn affects psychological set, and might further be influenced by personality characteristics. The observed modulation of the sensitivity of the ERP components by the context of stimulus presentation suggests that MFN and related ERP components are modulated by a switch in psychological set (e.g., from potential outcome, to evaluation of the decision). The fact that the correlations with personality were also subject to the context modulation further supports this hypothesis; individual differences in personality play a role in reward processing specific to the psychological set (or context), e.g., cognitive distortions have an effect when participant is evaluating behaviour but not during processing of potential outcome cues.

The results of both studies suggest that MFN and P3 components are modulated by the psychological sets of participants and reflect processing of nonperceptual characteristics of the stimulus. However, the responses of these components are sensitive to the context of the stimulus presentation. Thus, rather than reflecting processing of fixed stimulus characteristics these components are sensitive to those important for a given psychological set. The same person can have different ERP reactions to similar outcome in a reward-related situation depending on the context , which modulates their psychological sets.

The psychology of gambling is a wide topic that encompasses many fields and directions as understanding psychology of gambling implies understanding the reasons for one's behaviour. This research provides a starting point between integrating the knowledge and measure of several fields in order to examine the interactions between them. Further investigation of the practical applications of the proposed model of risk-taking behaviour as well as effects of various factors (e.g., neurotransmitter levels, personality, context) on each step will lead to more insights into the psychology of gambling. In conclusion, gambling behaviour should and can be examined from a variety of levels: neurobiological, personality and social. However, most importantly, all of these factors interact in order to produce the behaviour and thus the integration of knowledge among the fields is necessary.

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Table 2.1

Means and standard deviations of reaction times for various choices on the pure gambling task

Type of Trial	Type of wager	
	Large	Small
Large vs. Large	M =1159.48 SD = 436.57	—
Large vs. Small	M = 1137.26 SD = 340.99	M = 1167.06 SD = 433.15
Small vs. Large	—	M = 1075.18 SD = 378.12

Table 2.2

Means and Standard Deviations for the FRN amplitude across various sites for the four feedback conditions

Site	Large Loss	Small Loss	Large Win	Small Win
Fz	*M* = -1.37	*M* = -1.12	*M* = -0.49	*M* = -0.77
	SD = 2.06	*SD* = 1.71	*SD* = 1.98	*SD* = 1.61
FCz	*M* = -0.09	*M* = -0.16	*M* = 1.48	*M* = 0.92
	SD = 1.60	*SD* = 1.42	*SD* = 1.95	*SD* = 1.59
Cz	*M* = 0.92	*M* = 0.57	*M* = 2.28	*M* = 1.56
	SD = 2.00	*SD* = 1.73	*SD* = 1.95	*SD* = 1.77
CPz	*M* = 0.79	*M* = 1.98	*M* = 1.98	*M* = 1.45
	SD = 2.19	*SD* = 2.56	*SD* = 2.56	*SD* = 2.18

Table 2.3

Analysis of Variance for the FRN amplitude in response to the feedback, broken down by site

Site	Source	*df*	*F*	η^2	*p*
Fz	Valence (V)	1,28	4.04	.13	.054
	Magnitude (M)	1,28	<.02	<.01	.883
	V x M	1,28	3.45	.11	.074
FCz	Valence (V)	1,28	27.73	.49	<.001
	Magnitude (M)	1,28	4.84	.15	.036
	V x M	1,28	4.54	.14	.042
Cz	Valence (V)	1,28	11.12	.28	.002
	Magnitude (M)	1,28	13.13	.32	.001
	V x M	1,28	1.33	.05	.258
CPz	Valence (V)	1,28	12.89	.32	<.001
	Magnitude (M)	1,28	12.39	.31	<.001
	V x M	1,28	0.05	<.01	.828

Table 2.4

Means and Standard Deviations for the P300 amplitude across various sites for the four feedback conditions

Site	Large Loss	Small Loss	Large Win	Small Win
Fz	*M* = 1.57	*M* = 1.63	*M* = 0.79	*M* = 0.67
	SD = 1.85	*SD* = 1.77	*SD* = 1.83	*SD* = 1.78
FCz	*M* = 5.13	*M* = 4.52	*M* = 4.15	*M* = 4.85
	SD = 2.82	*SD* = 2.49	*SD* = 2.37	*SD* = 2.14
Cz	*M* = 6.01	*M* = 5.36	*M* = 5.81	*M* = 4.85
	SD = 3.09	*SD* = 2.89	*SD* = 2.48	*SD* = 2.14
CPz	*M* = 1.63	*M* = 4.58	*M* = 5.61	*M* = 4.80
	SD = 1.77	*SD* = 2.54	*SD* = 2.89	*SD* = 2.59

Table 2.5

Analysis of Variance for the P300 amplitude in response to the feedback, broken down by site

Site	Source	*df*	*F*	η^2	*p*
Fz	Valence (V)	1,28	7.52	.21	.011
	Magnitude (M)	1,28	0.04	<.01	.836
	V x M	1,28	0.23	.01	.638
FCz	Valence (V)	1,28	12.18	.30	.002
	Magnitude (M)	1,28	38.96	.58	<.001
	V x M	1,28	1.02	.04	.320
Cz	Valence (V)	1,28	1.90	.06	.179
	Magnitude (M)	1,28	25.85	.48	<.001
	V x M	1,28	0.75	.03	.395
PCz	Valence (V)	1,28	1.44	.05	.240
	Magnitude (M)	1,28	16.19	.37	<.001
	V x M	1,28	0.20	.01	.659

Table 2.6

Analysis of Variance for the FRN amplitude in response to the alternative card, broken down by site

Site	Source	*df*	*F*	η^2	*p*
Fz	Valence (V)	1,27	0.87	.03	.359
	Magnitude (M)	1,27	0.01	<.01	.914
	V x M	1,27	0.09	<.01	.769
FCz	Valence (V)	1,27	0.36	.01	.552
	Magnitude (M)	1,27	21.08	.45	<.001
	V x M	1,27	<.01	<.01	.979
Cz	Valence (V)	1,27	1.53	.05	.226
	Magnitude (M)	1,27	29.58	.52	<.001
	V x M	1,27	2.64	.09	.116
CPz	Valence (V)	1,26	0.64	.02	.432
	Magnitude (M)	1,26	15.78	.38	.001
	V x M	1,26	1.20	.04	.283

Table 2.7

Means and Standard Deviations for the FRN amplitude across various sites for the four conditions of the alternative card

Site	Large Loss	Small Loss	Large Win	Small Win
Fz	*M* = -1.18	*M* = -1.30	*M* = -1.01	*M* = -1.03
	SD = 1.58	*SD* = 1.41	*SD* = 1.75	*SD* = 1.12
FCz	*M* = 0.54	*M* = -0.30	*M* = 0.39	*M* = -0.37
	SD = 1.69	*SD* = 1.32	*SD* = 1.72	*SD* = 1.00
Cz	*M* = 1.41	*M* = 0.36	*M* = 1.39	*M* = 0.02
	SD = 1.82	*SD* = 1.36	*SD* = 1.75	*SD* = 1.14
CPz	*M* = 1.07	*M* = 0.20	*M* = 0.96	*M* = -0.10
	SD = 2.05	*SD* = 1.44	*SD* = 1.58	*SD* = 1.17

Table 2.8

Means and Standard Deviations for the P300 amplitude across various sites for the four conditions of the alternative card

Site	Large Loss	Small Loss	Large Win	Small Win
Fz	$M = 0.83$	$M = 1.42$	$M = 1.31$	$M = 0.60$
	$SD = 1.29$	$SD = 2.81$	$SD = 1.58$	$SD = 0.99$
FCz	$M = 3.82$	$M = 2.89$	$M = 3.39$	$M = 1.76$
	$SD = 4.96$	$SD = 1.80$	$SD = 1.89$	$SD = 1.17$
Cz	$M = 4.96$	$M = 3.58$	$M = 4.49$	$M = 2.20$
	$SD = 2.07$	$SD = 2.01$	$SD = 1.89$	$SD = 1.36$
CPz	$M = 4.49$	$M = 3.33$	$M = 4.33$	$M = 2.14$
	$SD = 2.32$	$SD = 1.72$	$SD = 1.84$	$SD = 1.46$

Table 2.9

Analysis of Variance for the P300 amplitude in response to the alternative card, broken down by site

Site	Source	*df*	*F*	η^2	*p*
Fz	Valence (V)	1,27	0.33	.01	.572
	Magnitude (M)	1,27	0.01	<.01	.936
	V x M	1,27	2.82	.09	.105
FCz	Valence (V)	1,28	8.22	.23	.008
	Magnitude (M)	1,28	36.92	.57	<.001
	V x M	1,28	4.14	.13	.051
Cz	Valence (V)	1,28	13.91	.33	.001
	Magnitude (M)	1,28	48.65	.64	<.001
	V x M	1,28	5.77	.17	.023
CPz	Valence (V)	1,28	10.97	.28	.003
	Magnitude (M)	1,28	44.82	.62	<.001
	V x M	1,28	7.40	.21	.011

Table 2.10

Follow-up analysis of the interaction between magnitude and valence of the alternative card found for the P3 amplitude, broken down by site and valence

Valence	Site	*df*	*F*	η^2	*p*
Win	FCz	1, 28	39.17	.58	<.001
	Cz	1, 28	87.44	.76	<.001
	CPz	1, 28	110.02	.80	<.001
Loss	FCz	1, 28	10.62	.28	.003
	Cz	1, 28	12.68	.32	.001
	CPz	1, 28	8.22	.24	.006

Table 2.11

Correlations between personality variables and FRN amplitude at Cz for the feedback condition

Questionnaire scores	Large Loss	Small Loss	Large Win	Small Win	Difference between Large and Small	Difference between Win and Loss
Behavioural Inhibition Scale ($N = 29$)	-.25	-.12	-.31	-.07	-.39*	-.14
Harm Avoidance ($N = 29$)	.06	.13	-.02	-.01	-.06	-.13
Sensitivity to Punishment ($N = 29$)	-.07	.02	-.01	.19	-.14	.11
Behavioural Activation Scale ($N = 28$)	-.21	-.15	-.14	-.37	.13	-.12
Sensation Seeking ($N = 26$)	-.32	-.43*	-.09	.08	-.07	.38
Sensitivity to Reward ($N = 27$)	.03	.02	.36	.18	.15	.39*
Perfectionism ($N = 29$)	.09	.09	-.05	-.09	.07	-.16
Neuroticism ($N = 28$)	-.37	-.22	-.29	-.39*	-.11	-.14
Conscientiousness ($N = 27$)	.36	.18	-.19	-.17	.03	-.39
Obsessive Compulsive Characteristics ($N = 28$)	-.01	-.01	.09	-.21	.40*	-.04
Cognitive distortions ($N = 29$)	-.09	-.07	.12	-.07	.14	.21
Delay discounting (k) ($N = 26$)	-.14	-.12	-.17	-.32	.10	-.16

*$p < .05$

Table 2.12

Correlations between personality variables and P300 amplitude at Cz for the feedback condition

Questionnaire scores	Large Loss	Small Loss	Large Win	Small Win	Difference between Large and Small	Difference between Win and Loss
Behavioural Inhibition Scale (*N* = 29)	-.23	-.19	-.14	-.04	-.24	.25
Harm Avoidance (*N* = 29)	.03	-.03	-.16	-.10	.03	.26
Sensitivity to Punishment (*N* = 29)	.18	.09	.01	.16	.02	-.26
Behavioural Activation Scale (*N* = 28)	-.33	-.35	-.31	-.34	.09	.08
Sensation Seeking (*N* = 26)	.08	.15	.09	.19	-.32	.06
Sensitivity to Reward (*N* = 27)	.30	.26	.31	.35	.04	.07
Perfectionism (*N* = 29)	-.07	-.03	.09	.19	-.26	.38*
Neuroticism (*N* = 28)	-.38*	-.36	-.43*	-.38*	-.12	-.04
Conscientiousness (*N* = 27)	-.08	-.08	-.01	.06	-.11	.22
Obsessive Compulsive Characteristics (*N* = 28)	.11	-.01	-.16	-.15	.23	-.43*
Cognitive distortions (*N* = 29)	.09	.13	-.15	<.01	-.26	.38*
Delay discounting (k) (*N* = 26)	-.25	-.31	-.17	-.19	.17	.21

* $p < .05$

Table 2.13

Correlations between personality variables and P300 amplitude at Fz for the feedback condition

Questionnaire scores	Large Loss	Small Loss	Large Win	Small Win	Difference between Large and Small	Difference between Win and Loss
Behavioural Inhibition Scale (N = 29)	.02	-.15	-.15	-.18	.15	-.17
Harm Avoidance (N = 29)	<.01	-.27	-.15	-.18	.29	-.12
Sensitivity to Punishment (N = 29)	-.09	-.02	-.11	-.20	.10	.22
Behavioural Activation Scale (N = 28)	.09	.31	-.03	.01	-.23	-.08
Sensation Seeking (N = 26)	.19	.47*	-.02	.03	-.25	-.12
Sensitivity to Reward (N = 27)	.29	.17	.13	.30	.03	.18
Perfectionism (N = 29)	<.01	-.09	.08	.15	.04	.15
Neuroticism (N = 28)	.17	.13	-.19	-.19	.02	-.28
Conscientiousness (N = 27)	-.21	-.35	.06	.05	.08	.16
Obsessive Compulsive Characteristics (N = 28)	.33	.22	.02	-.10	.29	-.14
Cognitive distortions (N = 29)	-.08	-.16	-.12	-.18	.09	.15
Delay discounting (k) (N = 26)	.06	.06	-.18	-.04	-.17	-.16

*p<.05

Table 2.14

Correlations between personality variables and FRN amplitude at Cz for the alternative card

Questionnaire scores	Large Loss	Small Loss	Large Win	Small Win	Win Joy	Lose Regret
Behavioural Inhibition Scale (*N* = 29)	-.13	.08	-.17	-.25	.01	-.37
Harm Avoidance (*N* = 29)	<.01	.05	-.05	-.03	.17	.12
Sensitivity to Punishment (*N* = 29)	.08	.11	.04	.17	.19	.04
Behavioural Activation Scale (*N* = 28)	-.16	-.17	.01	-.28	-.31	-.28
Sensation Seeking (*N* = 26)	.03	.26	.12	-.12	-.26	-.32
Sensitivity to Reward (*N* = 27)	-.11	.14	-.08	.16	.03	.14
Perfectionism (*N* = 29)	.18	.14	.08	.09	.18	.07
Neuroticism (*N* = 28)	-.37*	-.08	-.18	-.44*	-.30	-.42
Conscientiousness (*N* = 27)	.21	.39*	.01	.05	.39*	.01
Obsessive Compulsive Characteristics (*N* = 28)	.27	-.01	.37	.18	.12	.25
Cognitive distortions (*N* = 29)	-.11	.14	-.08	.39*	.01	.19
Delay discounting (k) (*N* = 26)	-.09	-.18	-.06	-.37	-.28	-.20

*p<.05

Table 2.15

Correlations between personality variables and P300 amplitude at Cz for the alternative card

Questionnaire scores	Large Loss	Small Loss	Large Win	Small Win	Win Joy	Lose Regret
Behavioural Inhibition Scale (N = 29)	-.03	-.09	-.16	-.02	-.11	-.06
Harm Avoidance (N = 29)	-.05	-.07	-.04	.01	-.01	.12
Sensitivity to Punishment (N = 29)	.26	.16	.11	.23	.23	.18
Behavioural Activation Scale (N = 28)	-.02	-.08	-.02	.04	-.08	-.08
Sensation Seeking (N = 26)	.06	.04	.03	-.09	-.02	-.21
Sensitivity to Reward (N = 27)	.21	.08	.22	.16	.25	<.01
Perfectionism (N = 29)	.17	.10	.11	.09	.12	.16
Neuroticism (N = 28)	-.15	-.07	-.03	-.06	-.18	-.14
Conscientiousness (N = 27)	.04	.14	.04	-.01	.07	.13
Obsessive Compulsive Characteristics (N = 28)	.33	.01	.47*	.52**	.38*	.44*
Cognitive distortions (N = 29)	-.11	.17	.25	.26	.16	.13
Delay discounting (k) (N = 26)	-.08	-.01	-.05	-.19	-.16	-.04

*p<.05; **p<.01

Table 2.16

Correlations between personality variables and FRN amplitude at Cz for the differences between alternative card, as well as combinations of alternative cards relative to the chosen one

Questionnaire scores	Large vs. Small	Win vs. Loss	Joy vs. Regret
Behavioural Inhibition Scale ($N = 29$)	-.10	-.32	-.37
Harm Avoidance ($N = 29$)	-.26	-.25	.08
Sensitivity to Punishment ($N = 29$)	-.10	-.06	.19
Behavioural Activation Scale ($N = 28$)	.17	.06	-.09
Sensation Seeking ($N = 26$)	-.03	.13	-.01
Sensitivity to Reward ($N = 27$)	-.08	.10	-.14
Perfectionism ($N = 29$)	.04	-.11	.14
Neuroticism ($N = 28$)	.01	-.07	-.05
Conscientiousness ($N = 27$)	-.10	-.40*	.16
Obsessive Compulsive Characteristics ($N = 28$)	.26	.25	-.12
Cognitive distortions ($N = 29$)	-.03	.25	-.26
Delay discounting (k) ($N = 26$)	.30	-.09	-.19

*p<.05

Table 2.17

Correlations between personality variables and P300 amplitude at Cz for the differences between alternative card, as well as combinations of alternative cards relative to the chosen one

Questionnaire scores	Large vs. Small	Win vs. Loss	Joy vs. Regret
Behavioural Inhibition Scale (*N* = 29)	-.07	-.08	-.11
Harm Avoidance (*N* = 29)	-.03	.04	-.18
Sensitivity to Punishment (*N* = 29)	.08	.03	.06
Behavioural Activation Scale (*N* = 28)	.01	.06	-.03
Sensation Seeking (*N* = 26)	.08	-.09	.28
Sensitivity to Reward (*N* = 27)	.19	.12	.43*
Perfectionism (*N* = 29)	.10	.01	-.02
Neuroticism (*N* = 28)	-.06	.06	-.13
Conscientiousness (*N* = 27)	-.02	-.06	-.06
Obsessive Compulsive Characteristics (*N* = 28)	.35	.54**	.04
Cognitive distortions (*N* = 29)	.16	.43*	.15
Delay discounting (k) (*N* = 26)	-.02	-.09	-.21

*p<.05

**p<.01

Table 2.18

Correlation coefficients between the ERP elicited by the feedback and the percentage of spending money used for gambling (N = 30).

ERP Component	*Site*	*Condition*	*Percentage of money spent on gambling*
FRN	Cz	Large Loss	0.10
		Small Loss	0.20
		Large Win	0.13
		Small Win	-0.21
		Difference between large and small	-0.18
		Difference between win and loss	0.06
P300	Cz	Large Loss	0.01
		Small Loss	0.10
		Large Win	0.13
		Small Win	0.05
		Difference between large and small	0.14
		Difference between win and loss	<.01
	Fz	Large Loss	0.22
		Small Loss	0.19
		Large Win	0.44*
		Small Win	0.34
		Difference between large and small	0.23
		Difference between win and loss	0.40*

*$p < .05$

Table 2.19

Correlation coefficients between the ERP elicited by the alternative card and the percentage of spending money used for gambling (N = 30).

ERP Component	*Site*	*Condition*	*Percentage of money spent on gambling*
FRN	Cz	Large Loss	-0.15
		Small Loss	-0.10
		Large Win	0.06
		Small Win	0.20
		Win Joy	0.13
		Lose Regret	-0.42*
		Large vs. Small	-0.08
		Win vs. Loss	0.50
		Joy vs. Regret	-0.77
P300	Cz	Large Loss	-0.48*
		Small Loss	-0.16
		Large Win	-0.11
		Small Win	-0.09
		Win Joy	-0.39
		Lose Regret	-0.23
		Large vs. Small	-0.35
		Win vs. Loss	0.25
		Joy vs. Regret	0.06

*$p < .05$

Table 3.1

Repeated measures ANOVA for the MFN amplitude elicited by the cues

Source	df_{effect}, df_{error}	F	$p\eta^2$	p	ε
Magnitude (M)	1, 29	4.62	.14	.040	-
Valence (V)	1, 29	6.62	.19	.016	-
Sites (C)	3, 87	18.42	.39	<.001	.48
M x V	1, 29	0.63	.02	.433	-
M x C	3, 87	6.12	.17	.010	.50
V x C	3, 87	2.62	.08	.093	.57
M x V x C	3, 87	3.86	.12	.029	.67

Table 3.2

Means and standard deviations for the MFN amplitude across the four midline sites elicited by the cues

Site	*Type of Cue*				
	Small Win	Small Loss	Zero	Large Win	Large Loss
Fz	$M = -2.96$	$M = -3.04$	$M = -2.88$	$M = -1.82$	$M = -2.75$
	$SD = 1.86$	$SD = 2.00$	$SD = 1.78$	$SD = 2.81$	$SD = 2.59$
FCz	$M = -2.45$	$M = -2.61$	$M = -2.75$	$M = -1.57$	$M = -2.31$
	$SD = 1.88$	$SD = 2.12$	$SD = 1.83$	$SD = 2.47$	$SD = 2.29$
Cz	$M = -0.98$	$M = -1.38$	$M = -1.41$	$M = -0.80$	$M = -1.10$
	$SD = 2.06$	$SD = 2.04$	$SD = 1.84$	$SD = 1.97$	$SD = 2.22$
CPz	$M = -0.27$	$M = -0.57$	$M = -1.09$	$M = -0.65$	$M = -0.63$
	$SD = 2.15$	$SD = 1.94$	$SD = 1.92$	$SD = 1.78$	$SD = 2.15$

Table 3.3

Repeated measures ANOVA for the MFN amplitude for individual sites elicited by the cues

Site	*Source*	df_{effect}, df_{error}	*F*	$p\eta^2$	*p*
Fz	Magnitude (M)	1, 29	7.63	.21	.010
	Valence (V)	1, 29	12.44	.30	.001
	M x V	1, 29	5.98	.17	.021
FCz	Magnitude (M)	1, 29	10.78	.27	.003
	Valence (V)	1, 29	6.74	.19	.015
	M x V	1, 29	1.74	.06	.198
Cz	Magnitude (M)	1, 29	2.02	.07	.166
	Valence (V)	1, 29	2.08	.07	.160
	M x V	1, 29	0.25	.01	.619
CPz	Magnitude (M)	1, 29	0.91	.03	.348
	Valence (V)	1, 29	0.05	<.01	.820
	M x V	1, 29	1.26	.04	.272

Table 3.4

Repeated measures ANOVA for the P300 amplitude elicited by the cues

Source	df_{effect}, df_{error}	*F*	$p\eta^2$	*p*	ε
Magnitude (M)	1, 30	0.84	.03	.367	-
Valence (V)	1, 30	0.96	.03	.336	-
Sites (C)	3, 90	79.30	.73	<.001	.53
M x V	1, 30	1.38	.04	.249	-
M x C	3, 90	0.11	<.01	.836	.49
V x C	3, 90	3.46	.10	.041	.63
M x V x C	3, 90	0.53	.02	.593	.67

Table 3.5

Repeated measures ANOVA for the P300 amplitude for the individual sites elicited by the cues

Site	*Source*	df_{effect}, df_{error}	*F*	η^2	*p*
Fz	Magnitude (M)	1, 30	0.33	.01	.570
	Valence (V)	1, 30	<.001	<.01	>.999
	M x V	1, 30	2.27	.07	.142
FCz	Magnitude (M)	1, 30	0.26	.01	.613
	Valence (V)	1, 30	<0.01	<.01	.965
	M x V	1, 30	1.07	.04	.309
Cz	Magnitude (M)	1, 30	0.45	.02	.508
	Valence (V)	1, 30	0.96	.03	.334
	M x V	1, 30	0.47	.02	.499
CPz	Magnitude (M)	1, 30	0.82	.03	.374
	Valence (V)	1, 30	5.91	.17	.021
	M x V	1, 30	0.11	<.01	.746

Table 3.6

Repeated measures ANOVA for the FRN amplitude elicited by feedback

Source	df_{effect}, df_{error}	F	$p\eta^2$	p	ε
Valence (V)	1, 28	7.40	.21	.011	-
Sites (C)	3, 84	12.41	.31	<.001	.45
V x C	3, 84	0.85	.03	.426	.61

Table 3.7

Means and standard deviations for the FRN amplitude across the four midline sites elicited by the feedback

Site	*Type of Feedback*	
	Win	Loss
Fz	*M* = -1.81	*M* = -1.57
	SD = 1.64	*SD* = 1.95
FCz	*M* = -1.12	*M* = -0.58
	SD = 1.87	*SD* = 2.01
Cz	*M* = 0.19	*M* = 0.90
	SD = 2.52	*SD* = 2.47
CPz	*M* = 0.17	*M* = 0.67
	SD = 2.70	*SD* = 2.68

Table 3.8

Repeated measures ANOVA for the FRN latency elicited by the feedback

Source	df_{effect}, df_{error}	F	$p\eta^2$	p	ε
Valence (V)	1, 28	5.86	.17	.022	-
Sites (C)	3, 84	7.33	.21	.006	.45
V x C	3, 84	3.39	.11	.053	.53

Table 3.9

Means and standard deviations for the FRN latency for individual sites for the feedback

Site	*Type of Feedback*	
	Win	Loss
Fz	*M* = 248.90	*M* = 274.45
	SD = 33.07	*SD* = 50.55
FCz	*M* = 248.65	*M* = 269.87
	SD = 30.33	*SD* = 38.09
Cz	*M* = 243.68	*M* = 257.61
	SD = 24.44	*SD* = 38.92
CPz	*M* = 237.94	*M* = 244.52
	SD = 33.46	*SD* = 43.03

Table 3.10

Repeated measures ANOVA for the P300 amplitude elicited by the feedback

Source	df_{effect}, df_{error}	*F*	$p\eta^2$	*p*	ε
Valence (V)	1, 28	2.50	.08	.125	-
Sites (C)	3, 84	62.70	.69	<.001	.64
V x C	3, 84	2.54	.08	.104	.50

Table 3.11

Means and standard deviations for the P300 amplitude elicited by the feedback

Site	Type of Feedback	
	Win	Loss
Fz	*M* = 1.41	*M* = 1.82
	SD = 2.15	*SD* = 2.32
FCz	*M* = 3.96	*M* = 4.84
	SD = 2.39	*SD* = 2.75
Cz	*M* = 6.06	*M* = 6.25
	SD = 2.12	*SD* = 2.89
CPz	*M* = 5.79	*M* = 5.70
	SD = 2.01	*SD* = 2.47

Table 3.12

Repeated measures ANOVA for the P300 latency elicited by the feedback

Source	df_{effect}, df_{error}	F	$p\eta^2$	p	ε
Valence (V)	1, 28	18.01	.39	<.001	-
Sites (C)	3, 84	1.83	.06	.148	.51
V x C	3, 84	1.94	.07	.160	.59

Table 3.13

Means and standard deviations for the P300 latency elicited by the feedback

Site	Type of Feedback	
	Win	Loss
Fz	*M* = 329.20	*M* = 377.53
	SD = 37.99	*SD* = 67.60
FCz	*M* = 240.58	*M* = 387.68
	SD = 35.20	*SD* = 44.40
Cz	*M* = 344.65	*M* = 376.19
	SD = 34.48	*SD* = 38.74
CPz	*M* = 342.06	*M* = 375.87
	SD = 36.48	*SD* = 47.79

Table 3.14

Correlation coefficients between the ERPs and the percentage of spending money used for gambling (N = 30).

ERP Component	*Site*	*Condition*	*Percentage of money spent on gambling*
MFN	Fz	Small Win Cue	.06
		Small Loss Cue	.03
		Zero Cue	.21
		Large Win Cue	.21
		Large Loss Cue	.15
		Large vs. Small Cues	.19
		Win vs. Loss Cues	.01
FRN	Cz	Lose Feedback	.03
		Win Feedback	.09
		Win vs. Loss Feedback	-.08
P300	CPz	Small Win Cue	-.10
		Small Loss Cue	-.10
		Zero Cue	-.17
		Large Win Cue	-.17
		Large Loss Cue	-.21
		Large vs. Small Cues	.31
		Win vs. Loss Cues	.27
	Cz	Lose Feedback	-.20
		Win Feedback	-.16
		Win vs. Loss Feedback	-.13

Table 3.15

Correlation coefficients between personality and the difference score elicited by the cues

Questionnaire scores	MFN Difference scores at Fz		P300 Difference scores at CPz	
	Large vs. Small	Win vs. Large	Large vs. Small	Win vs. Large
BIS (*N* = 30)	-.09	-.23	-.23	-.26
Harm Avoidance (*N* = 30)	.09	-.23	.12	.06
Sensitivity to Punishment (*N* = 30)	.04	-.08	-.15	-.10
BAS (*N* = 29)	-.21	.16	-.29	-.20
Sensation Seeking (*N* = 28)	-.10	.14	-.37	-.31
Sensitivity to Reward (*N* = 29)	.14	-.16	-.27	-.42*
Perfectionism (*N* = 30)	.25	-.07	.18	-.14
Neuroticism (*N* = 30)	-.11	-.07	-.37*	-.03
Conscientiousness (*N* = 29)	.38*	-.01	.26	-.18
Obsessive Compulsive Characteristics (*N* = 30)	.12	.37*	.30	.12
Cognitive distortions (*N* = 30)	.49*	.24	.29	-.01
Delay discounting (k) (*N* = 28)	.05	-.08	-.06	.16

$*p < .05$

Table 3.16

Correlation coefficients between personality and the MFN amplitude at Fz elicited by the cues

Questionnaire scores	Small Win	Small Loss	Large Win	Large Loss
BIS ($N = 30$)	.07	.06	<.01	-.03
Harm Avoidance ($N = 30$)	.49**	.43*	.48**	.33
Sensitivity to Punishment ($N = 30$)	-.08	<.01	-.02	-.11
BAS ($N = 29$)	.01	-.06	-.20	.01
Sensation Seeking ($N = 28$)	-.28	-.38*	-.45*	-.25
Sensitivity to Reward ($N = 29$)	.16	.10	.20	.25
Perfectionism ($N = 30$)	.31	.28	.32	.35
Neuroticism ($N = 30$)	.06	.02	-.03	.04
Conscientiousness ($N = 29$)	.29	.08	.25	.27
Obsessive Compulsive Characteristics ($N = 30$)	.25	.34	.26	.24
Cognitive distortions ($N = 30$)	.19	.17	.37*	.36
Delay discounting (k) ($N = 28$)	-.08	<.01	-.02	-.11

*$p < .05$

** $p < .01$

Table 3.17

Correlation coefficients between the personality variables and the P300 amplitude at CPz elicited by the cues

Questionnaire scores	Small Win	Small Loss	Large Win	Large Loss
BIS ($N = 30$)	-.25	-.21	-.18	-.20
Harm Avoidance ($N = 30$)	<.01	-.36*	-.06	.18
Sensitivity to Punishment ($N = 30$)	.02	.02	.18	.11
BAS ($N = 29$)	-.32	-.10	-.33	-.34
Sensation Seeking ($N = 28$)	-.03	.39*	.17	-.06
Sensitivity to Reward ($N = 29$)	.09	.09	.22	.02
Perfectionism ($N = 30$)	.01	-.32	-.01	-.15
Neuroticism ($N = 30$)	-.15	-.03	-.05	.06
Conscientiousness ($N = 29$)	.21	-.12	.11	-.21
Obsessive Compulsive Characteristics ($N = 30$)	.15	.02	-.12	-.09
Cognitive distortions ($N = 30$)	.12	-.10	.22	-.05
Delay discounting (k) ($N = 28$)	.02	.20	.05	.20

*$p < .05$

Table 3.18

Correlation coefficients between personality and the ERP amplitude elicited by the zero cues

Questionnaire scores	MFN amplitude at Fz	P300 amplitude at CPz
BIS ($N = 30$)	.07	-.42*
Harm Avoidance ($N = 30$)	.44*	.11
Sensitivity to Punishment ($N = 30$)	-.03	.08
BAS ($N = 29$)	-.15	-.22
Sensation Seeking ($N = 28$)	-.29	-.16
Sensitivity to Reward ($N = 29$)	.21	.18
Perfectionism ($N = 30$)	.36*	-.29
Neuroticism ($N = 30$)	-.09	.08
Conscientiousness ($N = 29$)	.18	-.03
Obsessive Compulsive Characteristics ($N = 30$)	.28	.21
Cognitive distortions ($N = 30$)	.43*	.07
Delay discounting (k) ($N = 28$)	.03	.42*

*$p < .05$

Table 3.19

Correlation coefficients between the personality variables and the FRN amplitude at Cz elicited by the feedback

Questionnaire scores	Win	Loss	Win vs. Loss
BIS ($N = 30$)	-.25	-.34	-.24
Harm Avoidance ($N = 30$)	.40*	.42*	.17
Sensitivity to Punishment ($N = 30$)	-.09	-.12	.05
BAS ($N = 29$)	-.05	-.13	-.17
Sensation Seeking ($N = 28$)	-.40*	-.29	.06
Sensitivity to Reward ($N = 29$)	.22	.23	.10
Perfectionism ($N = 30$)	-.02	-.03	-.02
Neuroticism ($N = 30$)	<.01	-.08	-.15
Conscientiousness ($N = 29$)	.11	.15	.12
Obsessive Compulsive Characteristics ($N = 30$)	-.10	-.01	.14
Cognitive distortions ($N = 30$)	-.12	<.01	.18
Delay discounting (k) ($N = 28$)	.09	.05	-.07

*$p < .05$

** $p < .01$

Table 3.20

Correlation coefficients between the personality variables and the P300 amplitude at Cz elicited by the feedback

Questionnaire scores	Win	Loss	Win vs. Loss
BIS ($N = 30$)	.21	.10	-.11
Harm Avoidance ($N = 30$)	.62**	.36*	-.20
Sensitivity to Punishment ($N = 30$)	.18	.17	.02
BAS ($N = 29$)	-.06	.15	.31
Sensation Seeking ($N = 28$)	-.08	-.01	.08
Sensitivity to Reward ($N = 29$)	.34	.43*	.26
Perfectionism ($N = 30$)	.29	.15	-.13
Neuroticism ($N = 30$)	.16	-.05	-.26
Conscientiousness ($N = 29$)	.07	.10	.07
Obsessive Compulsive Characteristics ($N = 30$)	.06	.07	.05
Cognitive distortions ($N = 30$)	-.06	-.11	-.11
Delay discounting (k) ($N = 28$)	-.08	-.04	.04

*$p < .05$

** $p < .01$

Figure 2.1

The sequence of events during a trial of the pure gambling task.

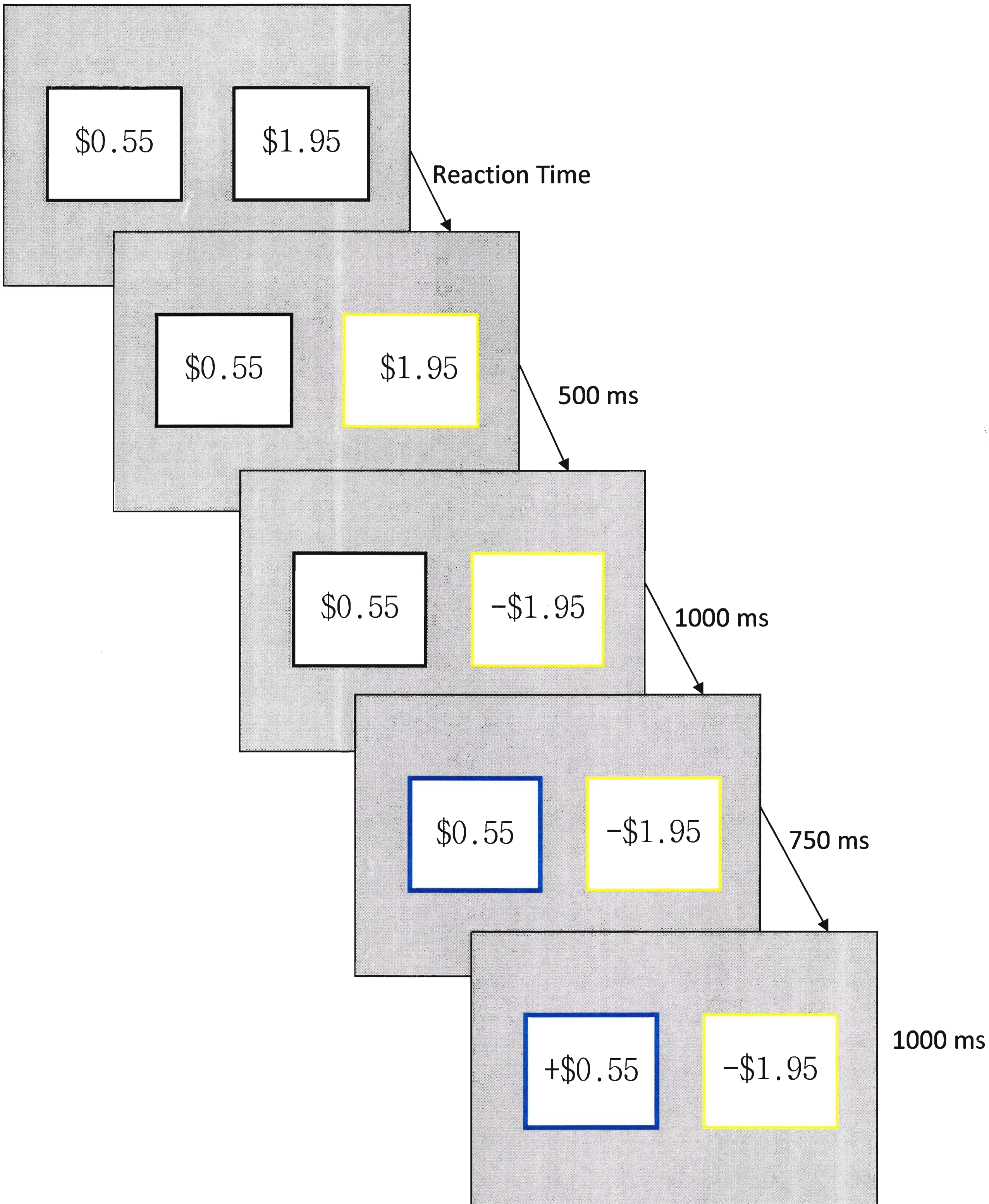


Figure 2.2

Comparison of mean reaction times with standard deviations for different wagers during the pure gambling task

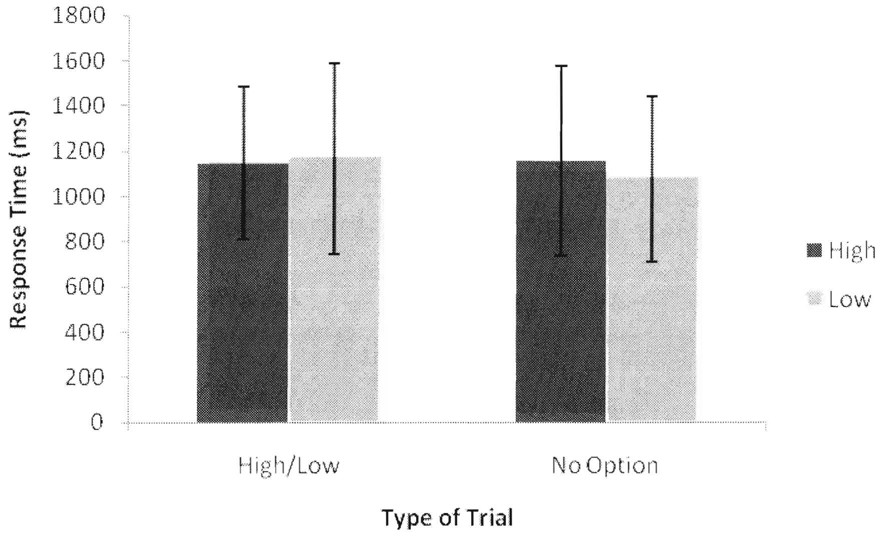
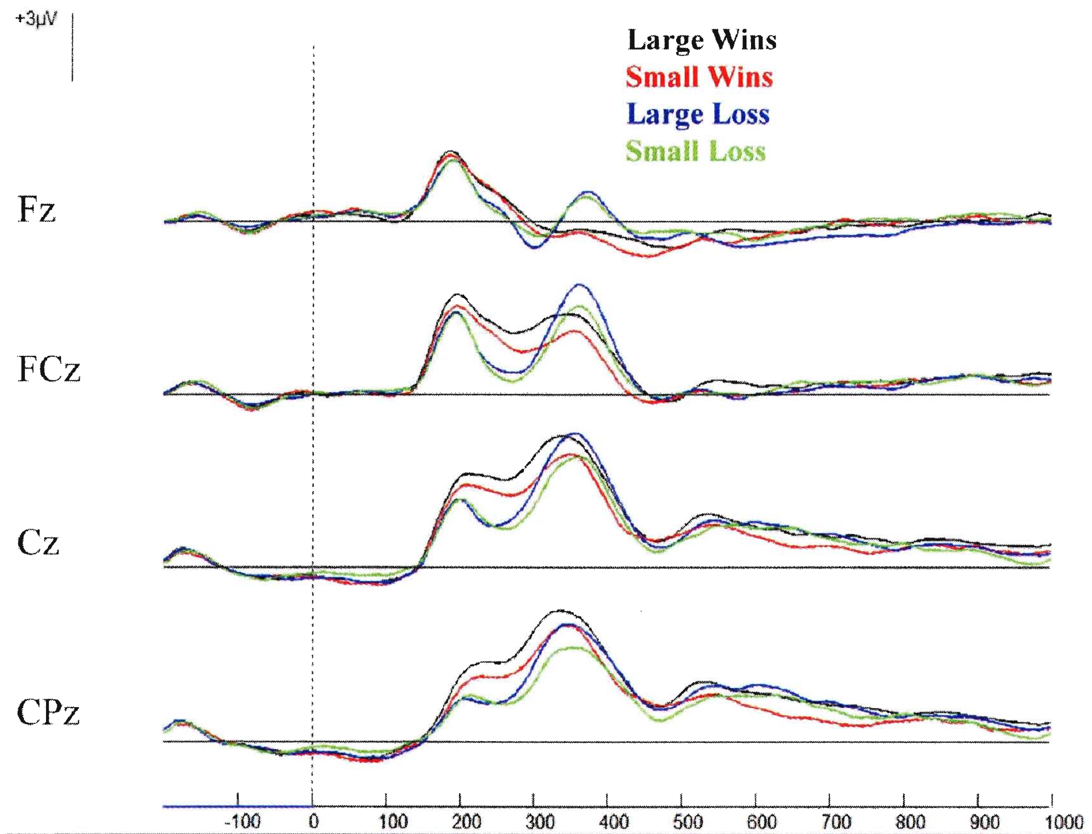


Figure 2.3

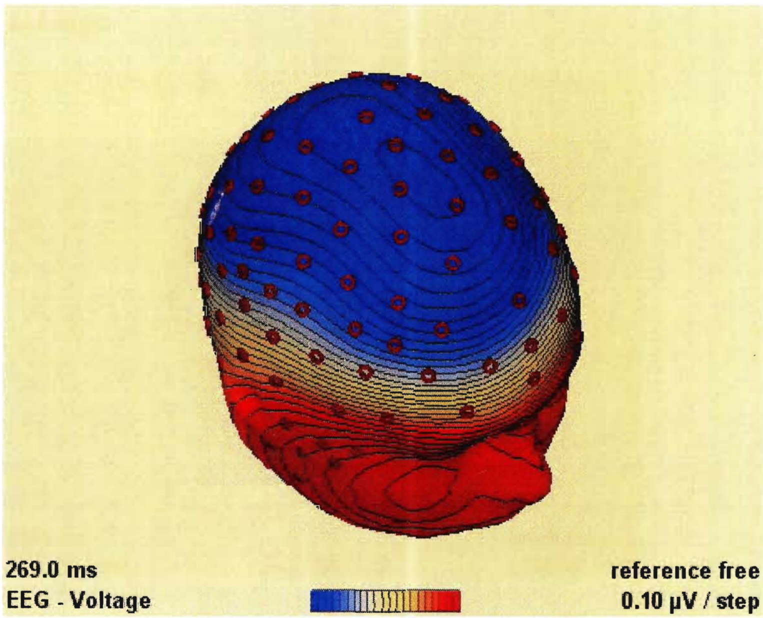
Averaged ERP waveforms for the four types of feedback received during the pure gambling task



Note: FRN component differentiates between wins and losses on the majority of the channels, while the P3 component differentiates valence at Fz, but is more sensitive to the amplitude of the wager on the other channels.

Figure 2.4

Grand average topographical map of the difference in the FRN between loss and win feedback in the pure gambling task (Study 1).

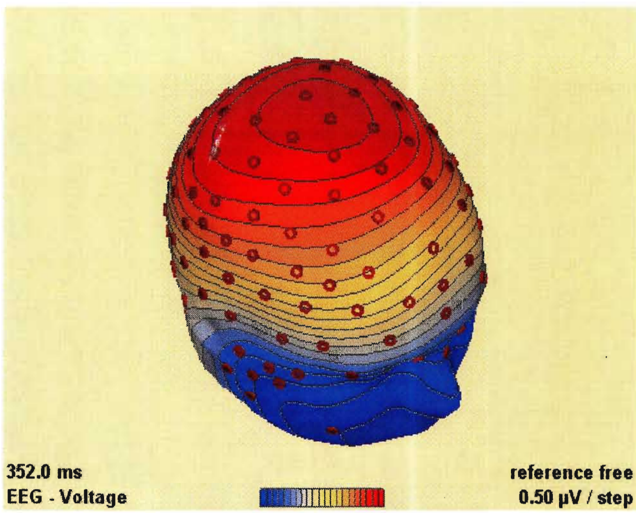


Note. The difference in the FRN amplitude between win and loss conditions was used for the topographical maps because the FRN amplitudes observed in these conditions were above the baseline (i.e., but much less positive than the preceding P2 and following P3). Losses elicited large FRN amplitude (i.e., more negative) when compared to wins.

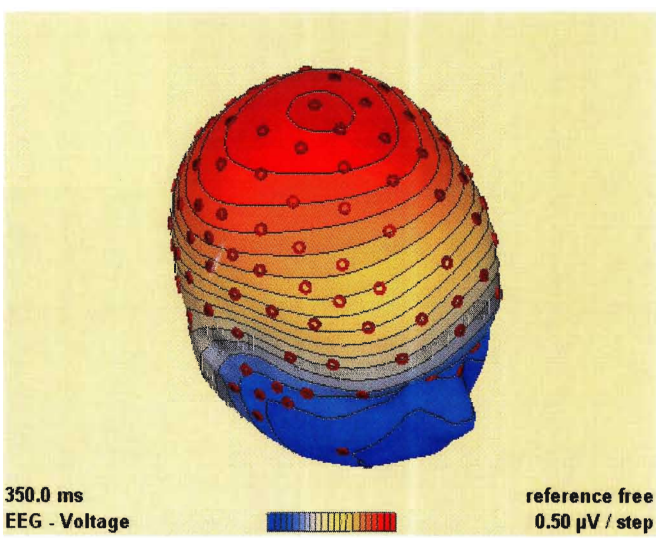
Figure 2.5

Grand average topographical map of the P3 for the feedback given after large and small wagers in the pure gambling task (Study 1).

a. Large



b. Small

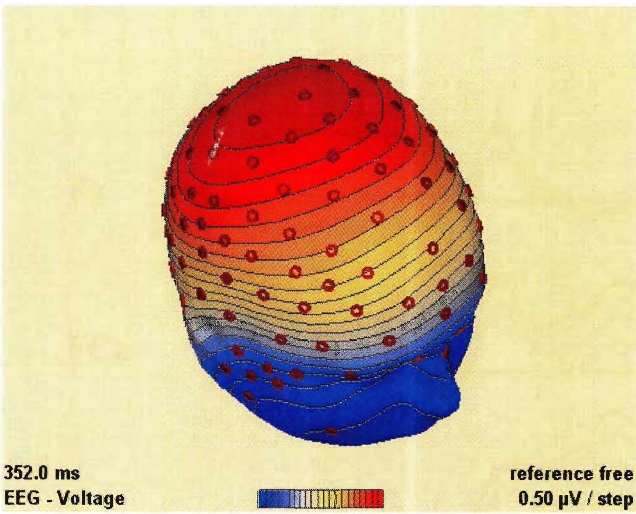


Note. Feedback following large wagers elicited larger P3 amplitude.

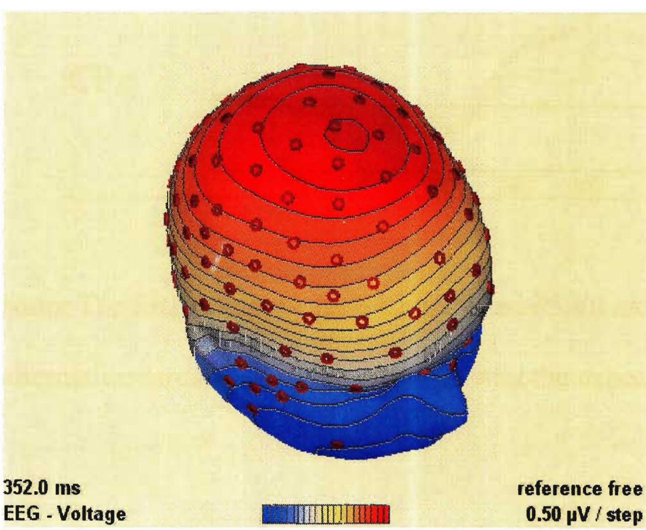
Figure 2.6

Grand average topographical map of the P3 for the win and loss feedback conditions of the pure gambling task.

a) Win



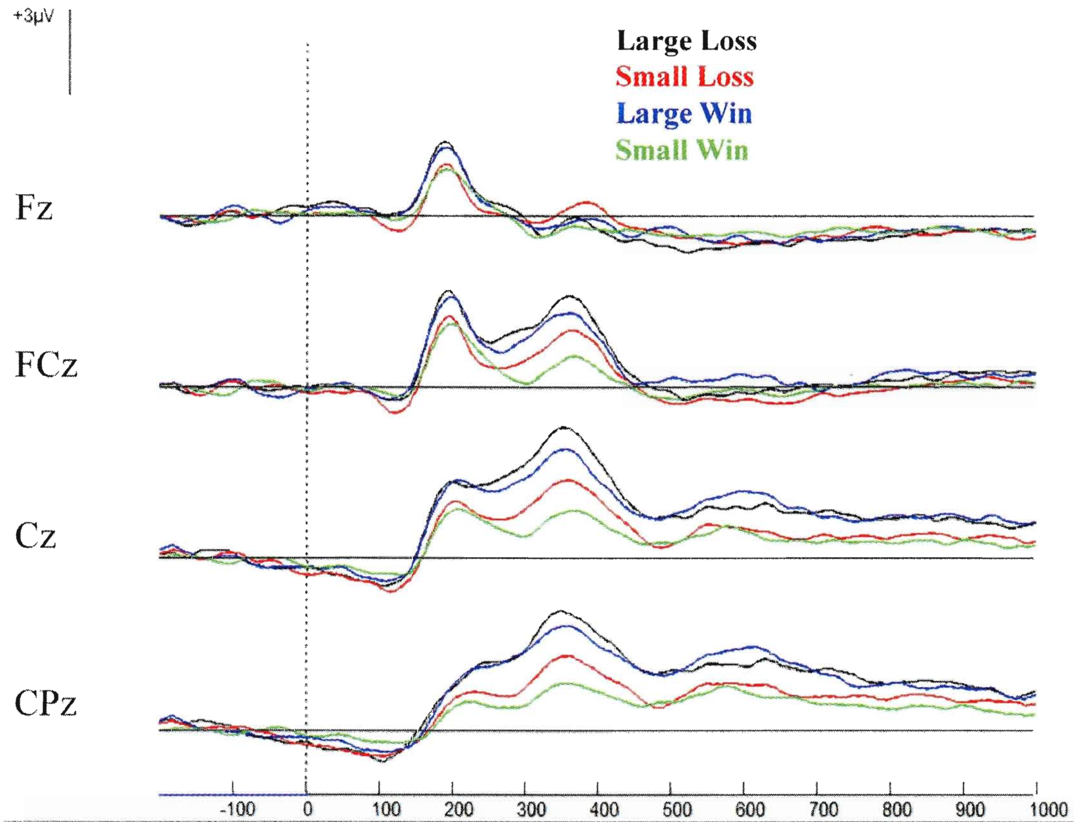
b) Loss



Note. Losses elicited larger P3 amplitude, but this effect was observed only at Fz and FCz (Table 2.5).

Figure 2.7

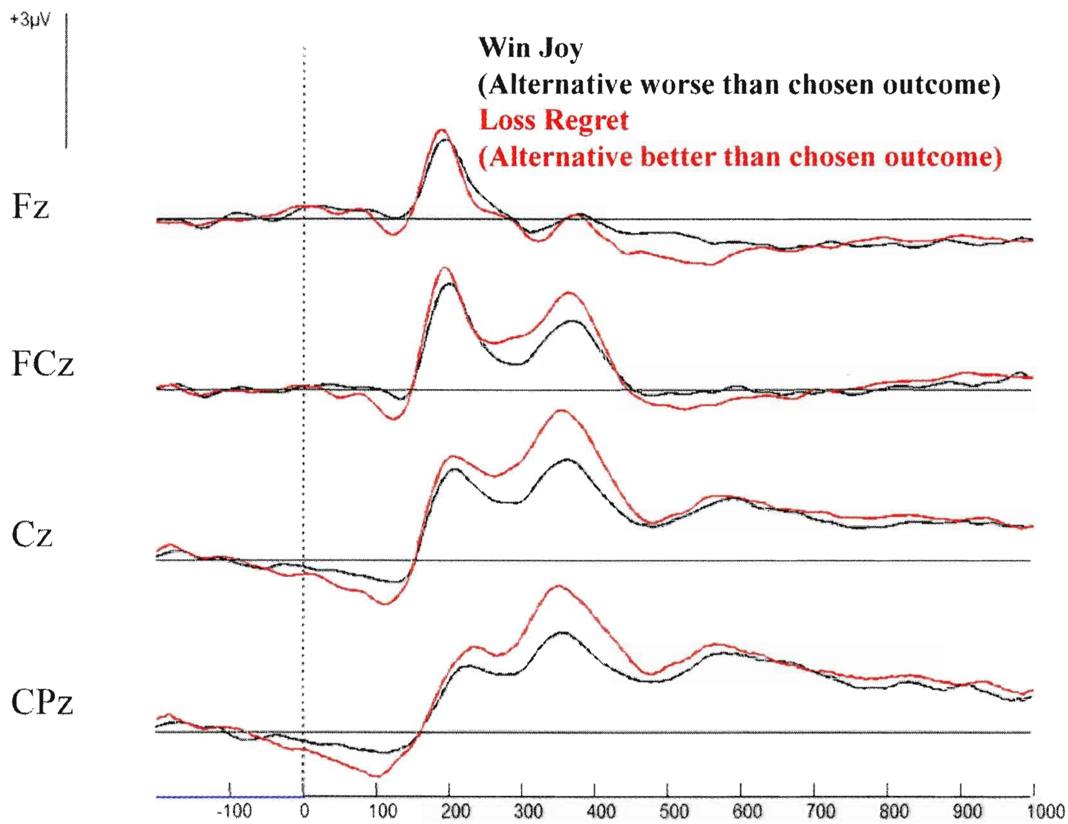
Average ERP waveforms for the four types of the alternative card presented during the pure gambling task



Note: The ERP componnets (i.e., FRN and P300) are separating the four types of alternative cards at all of the channels wiht the expection of Fz.

Figure 2.8

Average ERP waveforms for the four types of the alternative card presented during the pure gambling task



Note: When the alternative card was a better choice and the chosen card was a loss (i.e., loss regret condition) there is an overall positivity starting at around 200 ms after the presentation of the alternative card and lasts for about 300 ms.

Figure 2.9

Scatter plots for the FRN amplitude at Cz during the small losses and sensation seeking scores

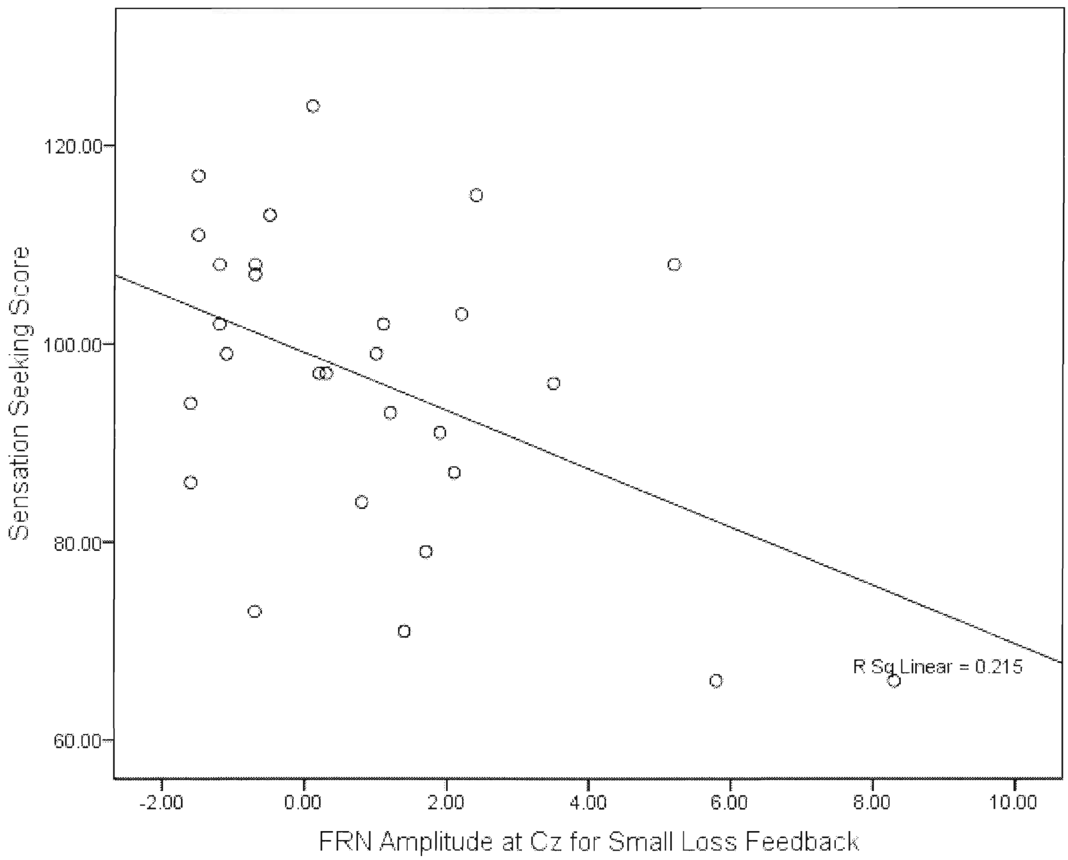


Figure 2.10

Scatter plots for the P300 amplitude at Fz during the small losses and sensation seeking scores

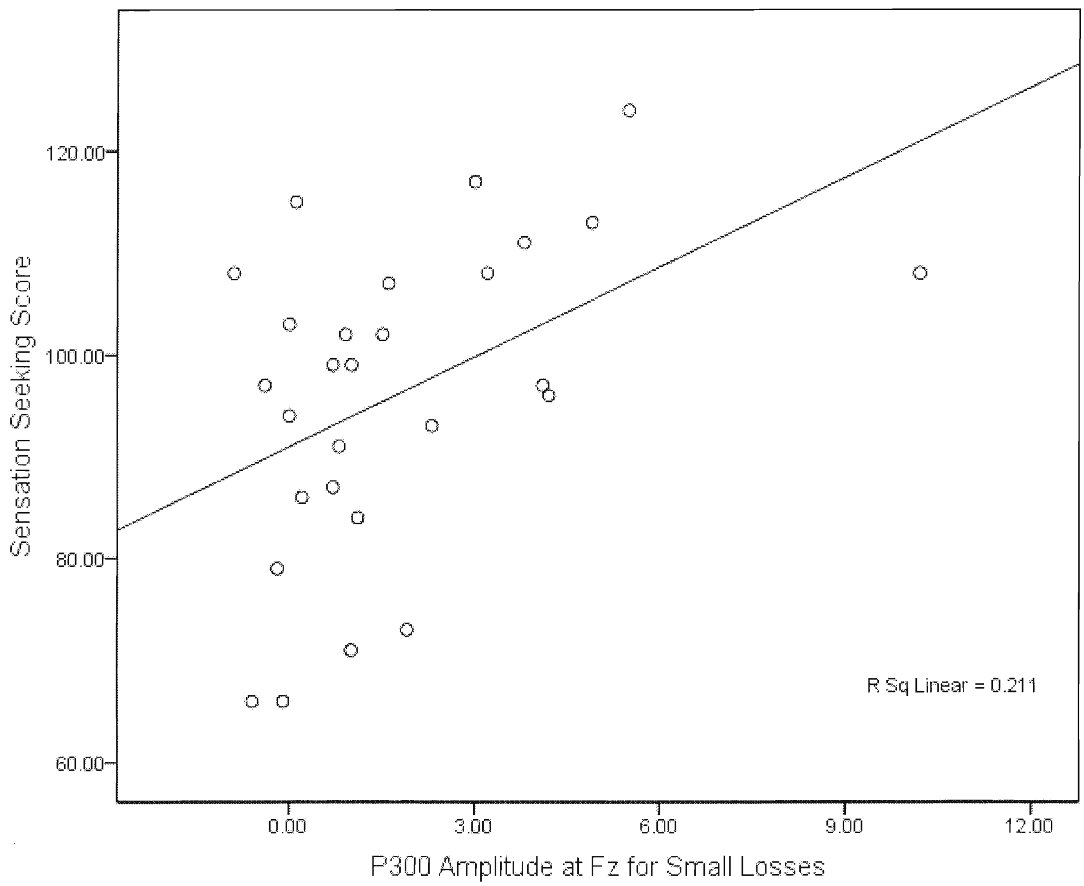


Figure 2.11

Scatter plots for the FRN amplitude at Cz during the small wins and neuroticism scores

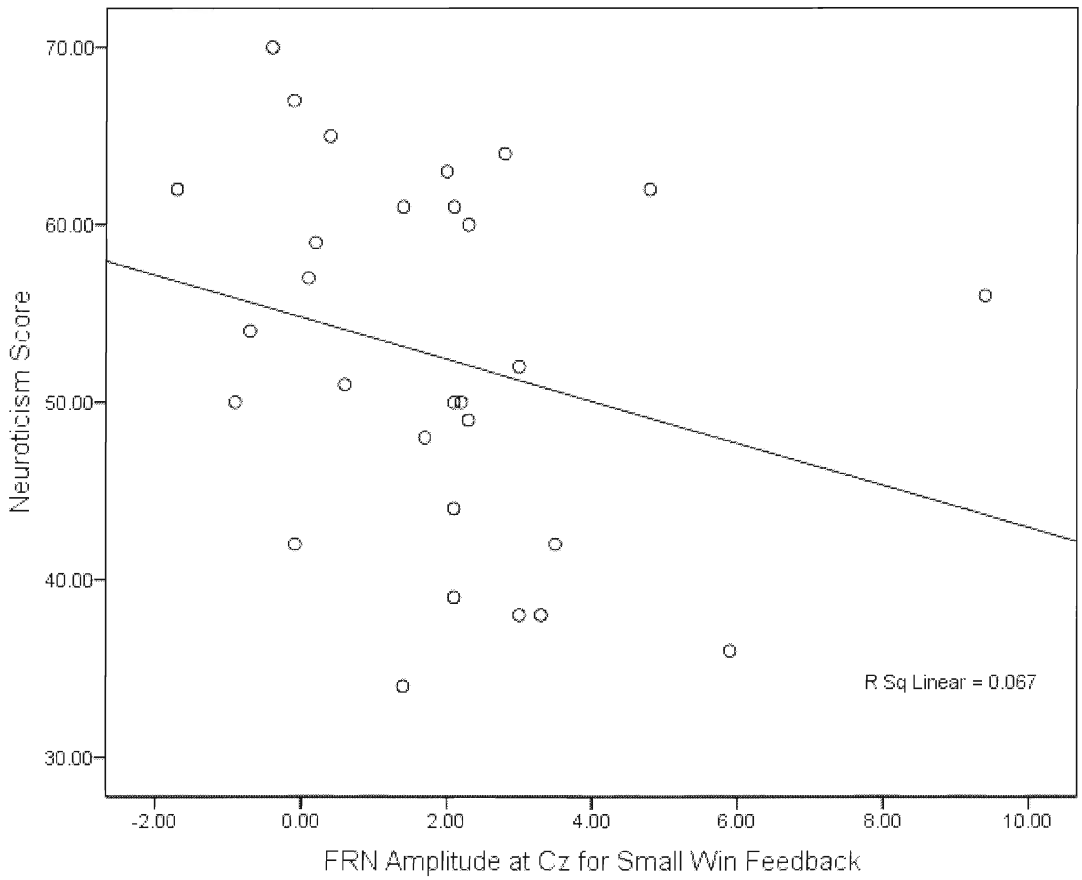


Figure 2.12

Scatter plots for the P300 amplitude at Cz during the small wins and neuroticism scores

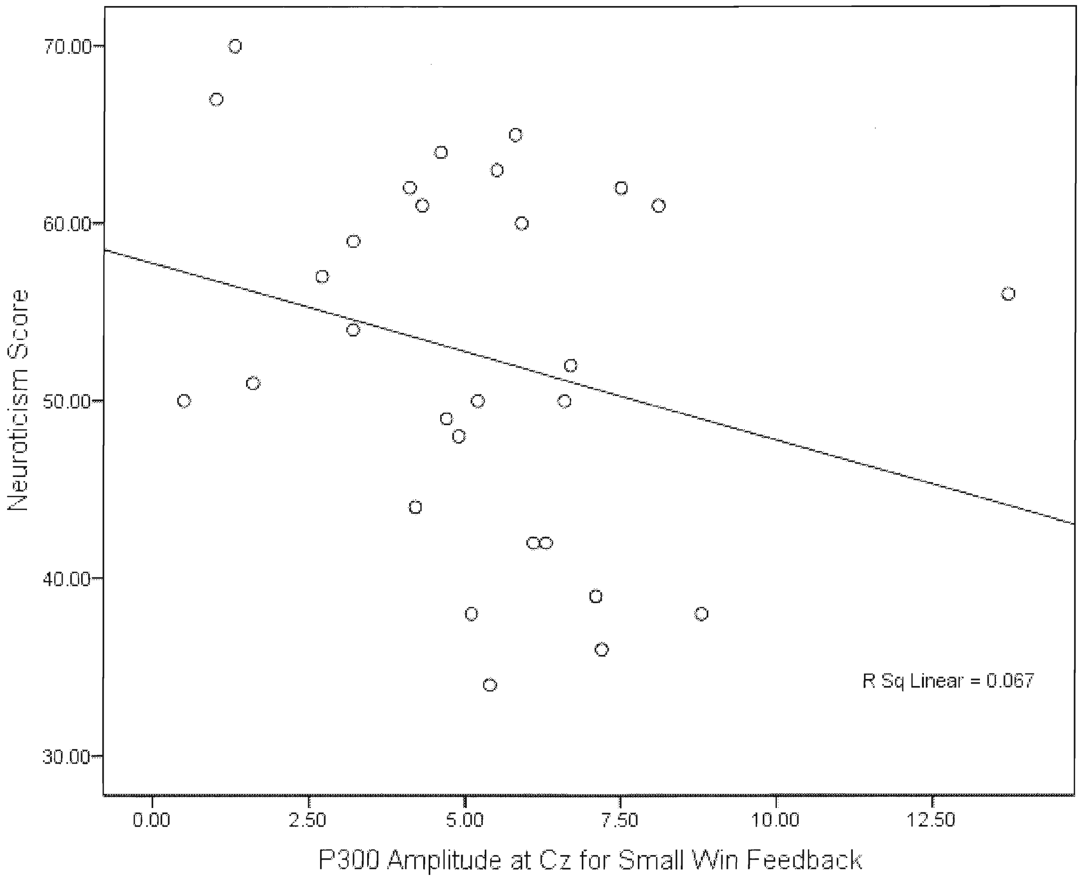


Figure 2.13

Scatter plots for the P300 amplitude at Cz during large wins and neuroticism scores

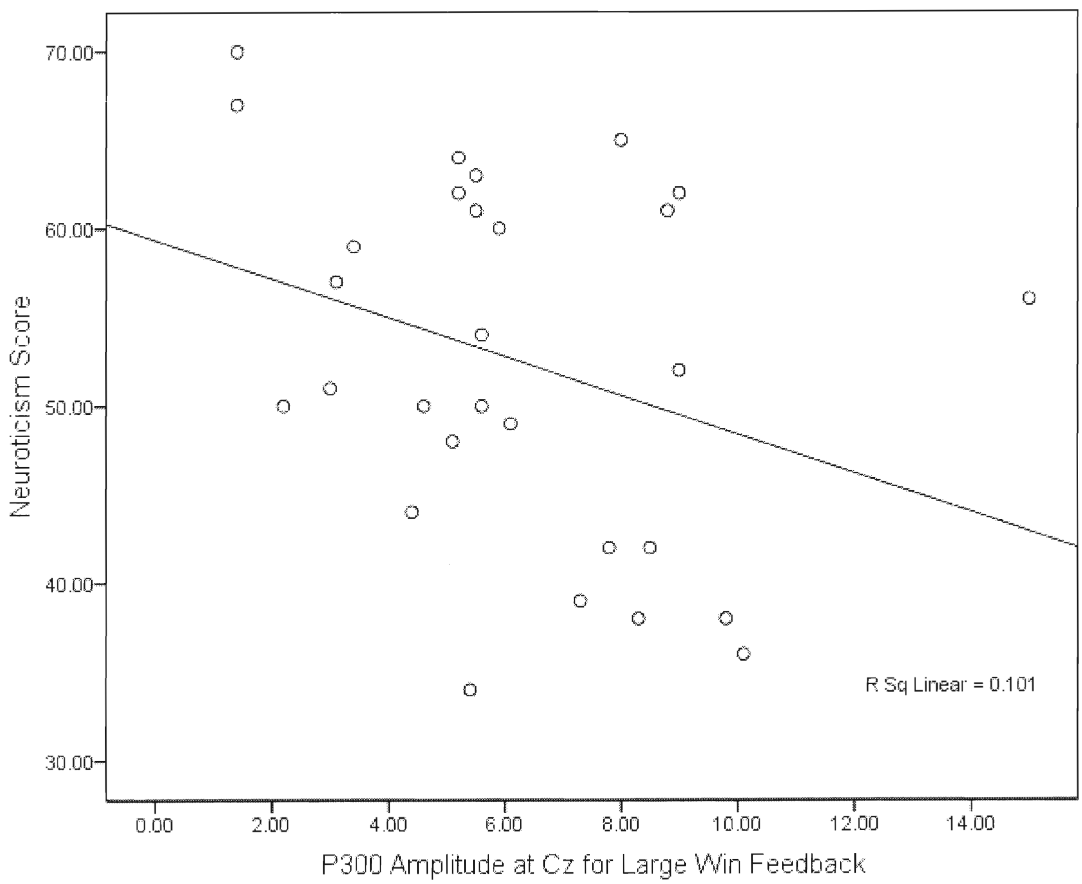


Figure 2.14

Scatter plots for the P300 amplitude at Cz during large losses and neuroticism scores

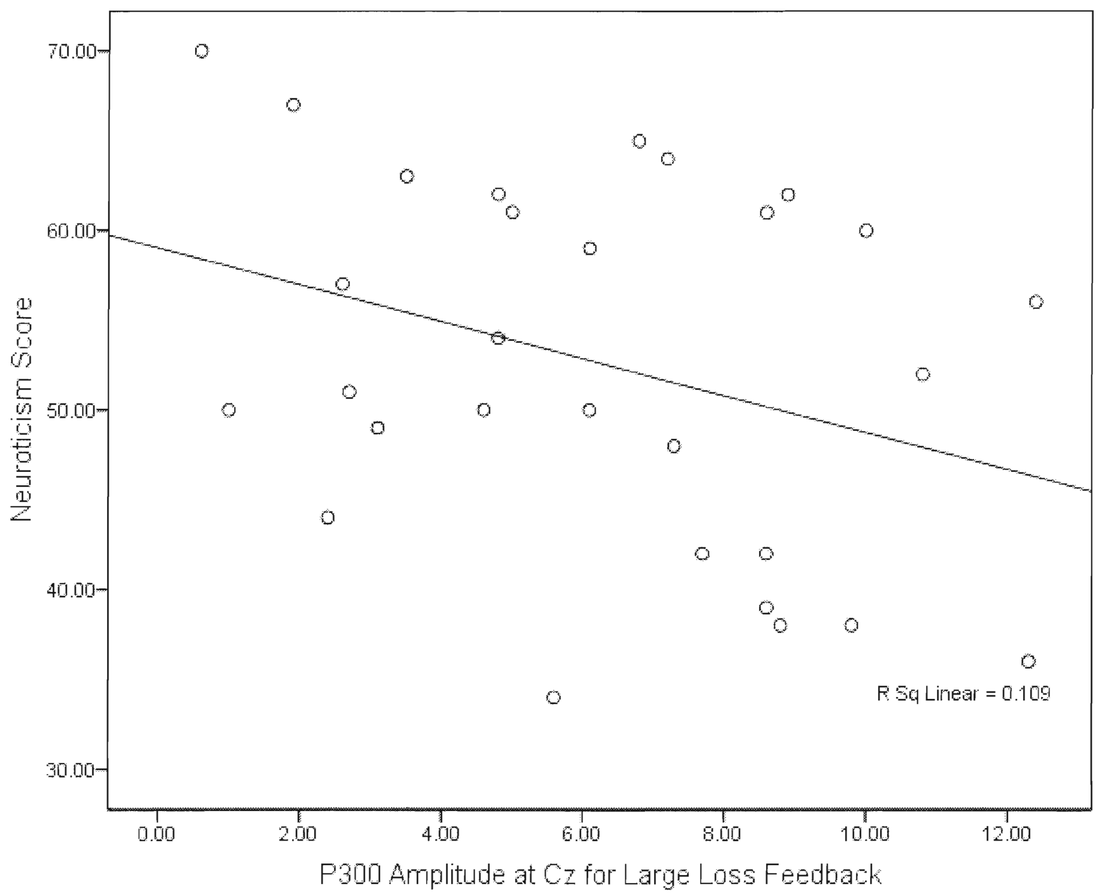


Figure 2.15

Scatter plots for the difference in FRN amplitude at Cz between feedback on large and small wagers and BIS scores

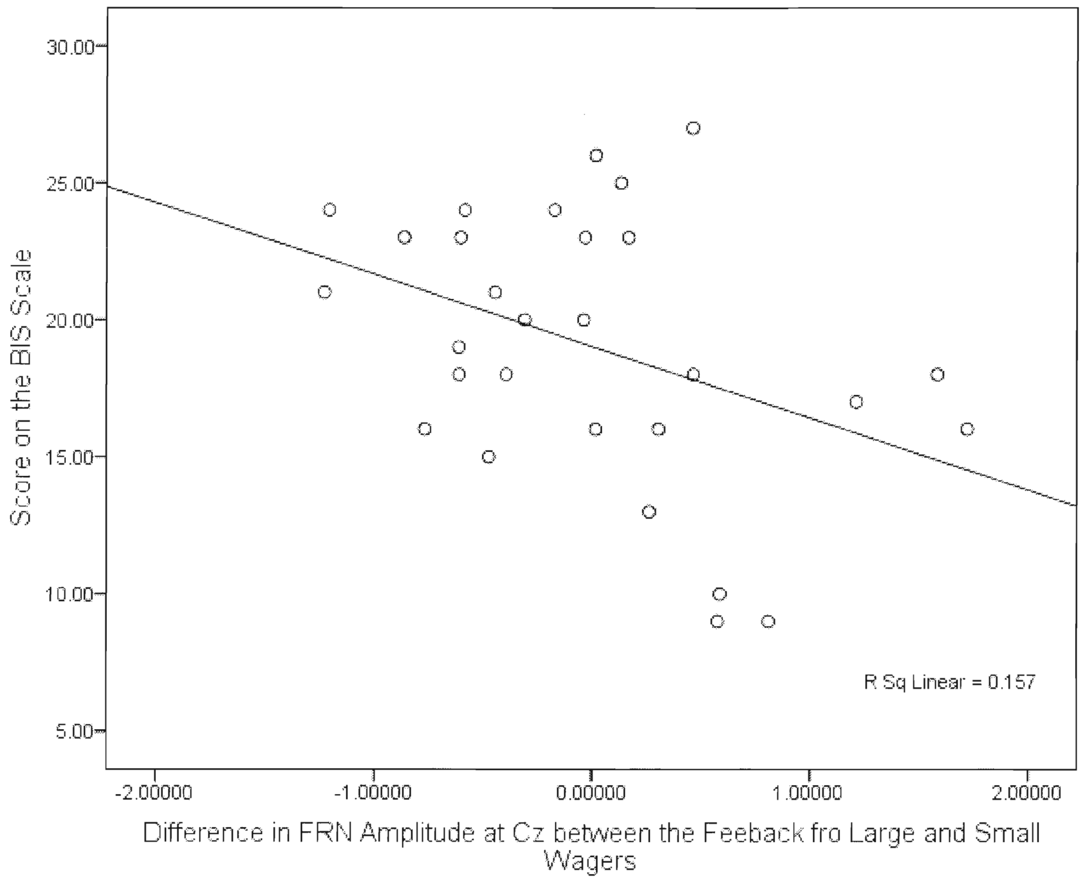


Figure 2.16

Scatter plots for the difference in FRN amplitude at Cz between feedback on large and small wagers and scores on the obsessive compulsive characteristic measure

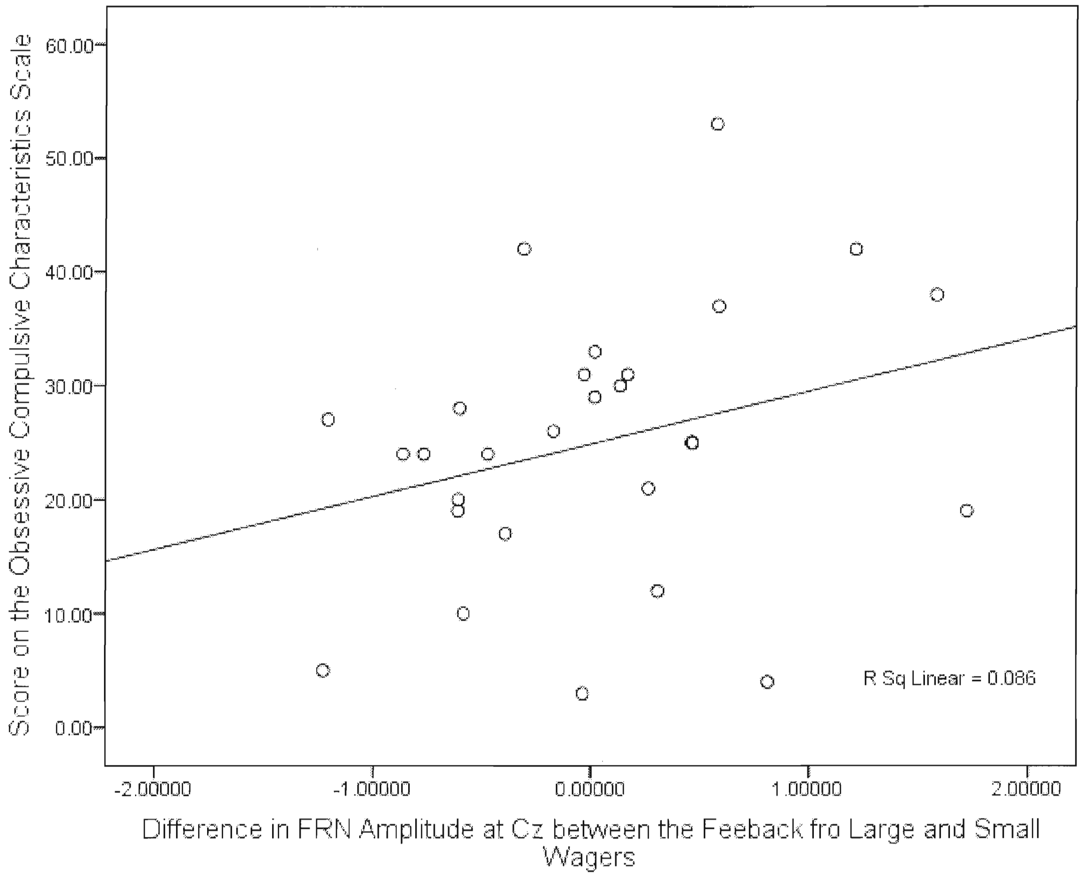


Figure 2.17

Scatter plots for the difference in FRN amplitude at Cz between win and loss feedback and sensitivity to reward scores

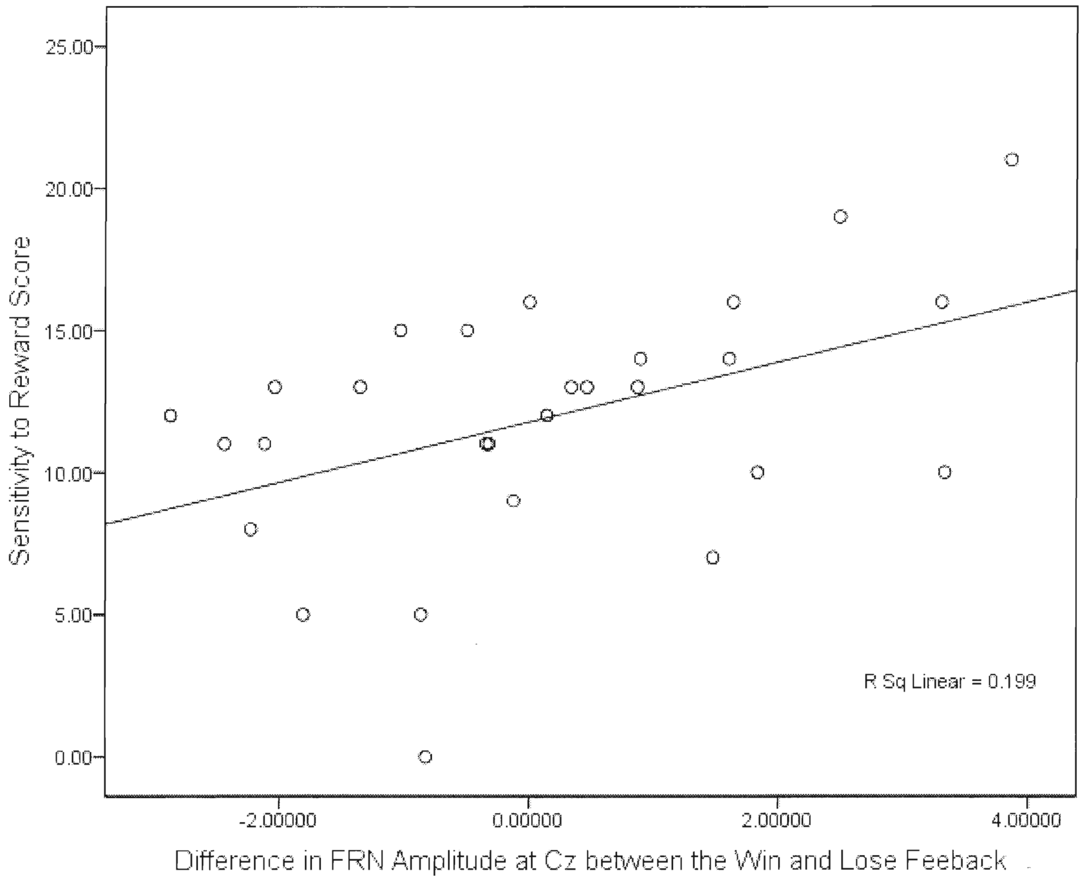


Figure 2.18

Scatter plots for the difference in P300 amplitude at Cz between wins and losses and levels of reported cognitive distortions

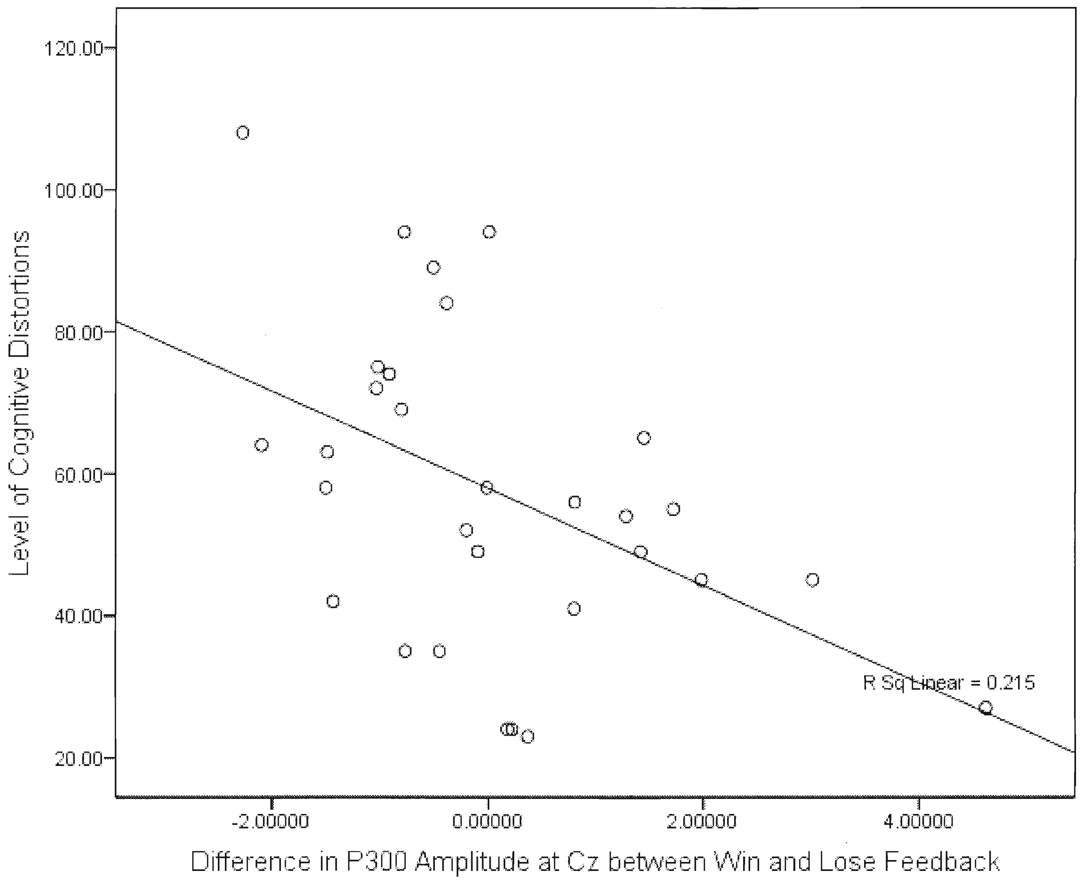


Figure 2.19

Scatter plots for the difference in P300 amplitude at Cz between wins and losses and levels of obsessive compulsive characteristics

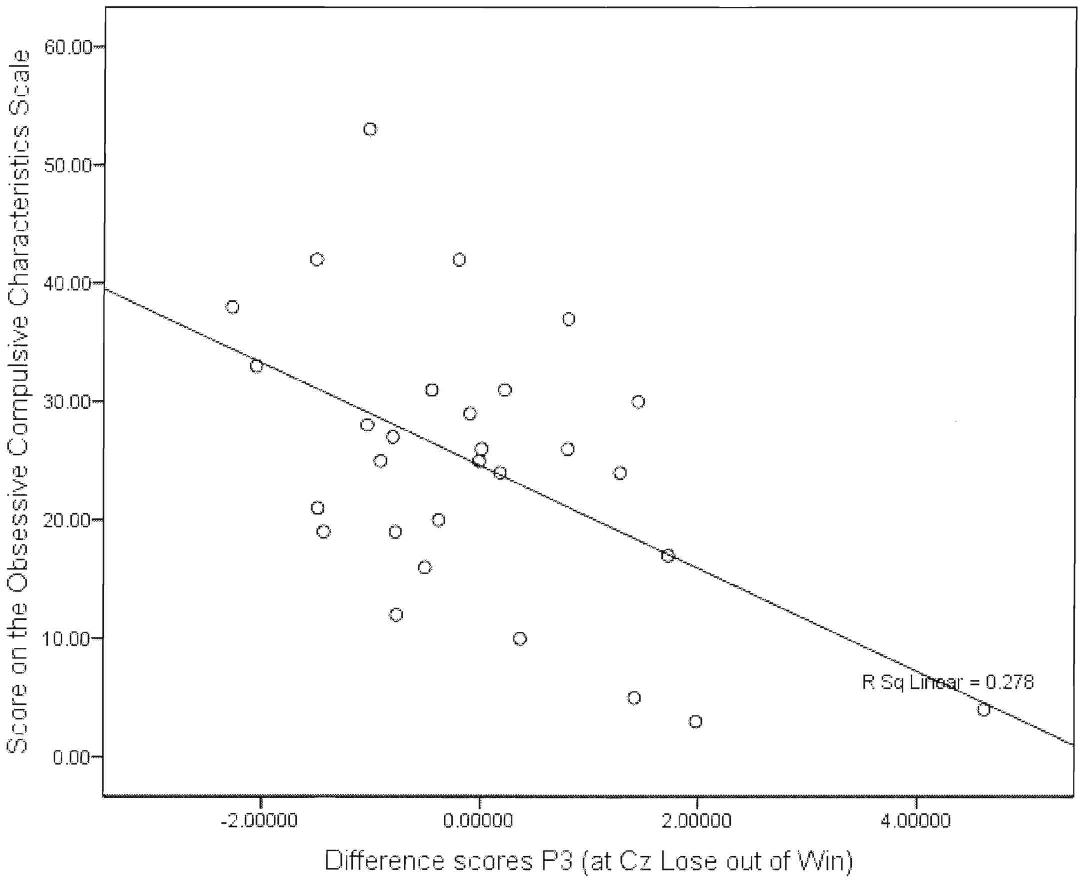


Figure 2.20

Scatter plots for the difference in P300 amplitude at Cz between wins and losses and perfectionism scores

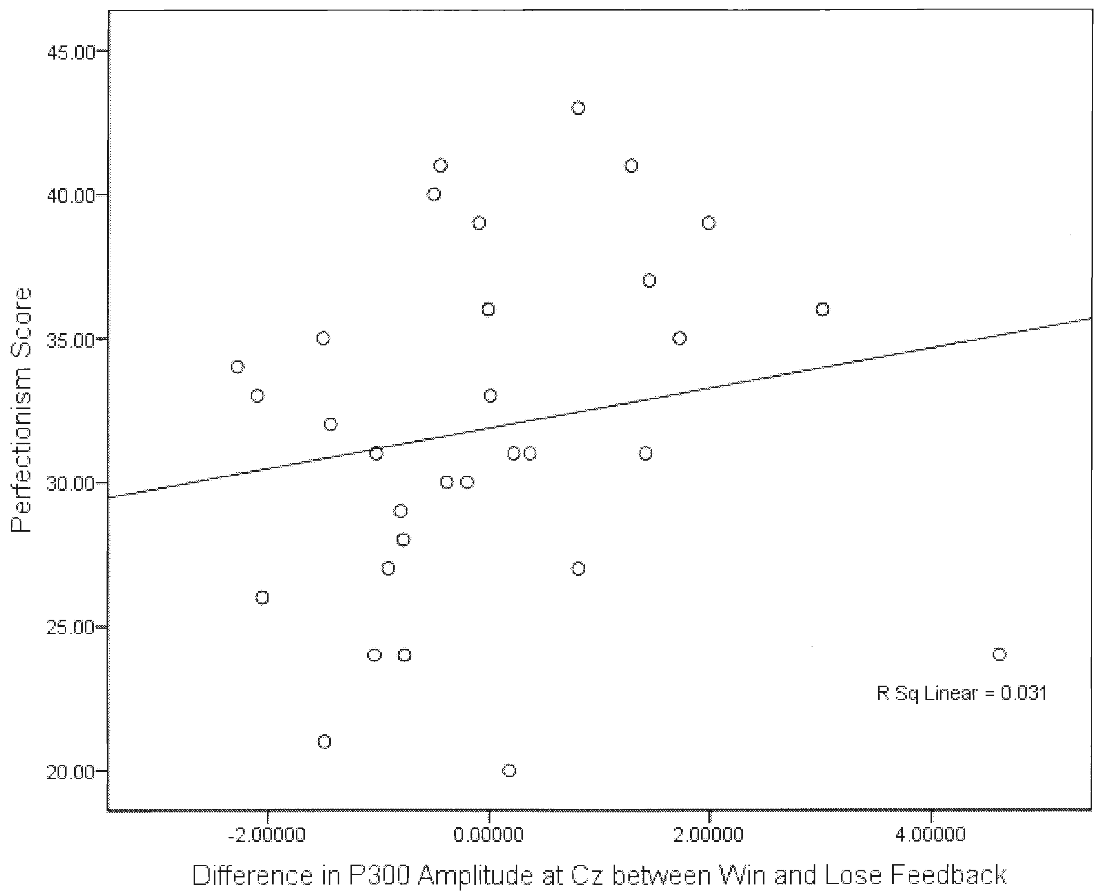


Figure 2.21

Scatter plots for the P300 amplitude at Fz for large wins and percentage of spending money used for gambling

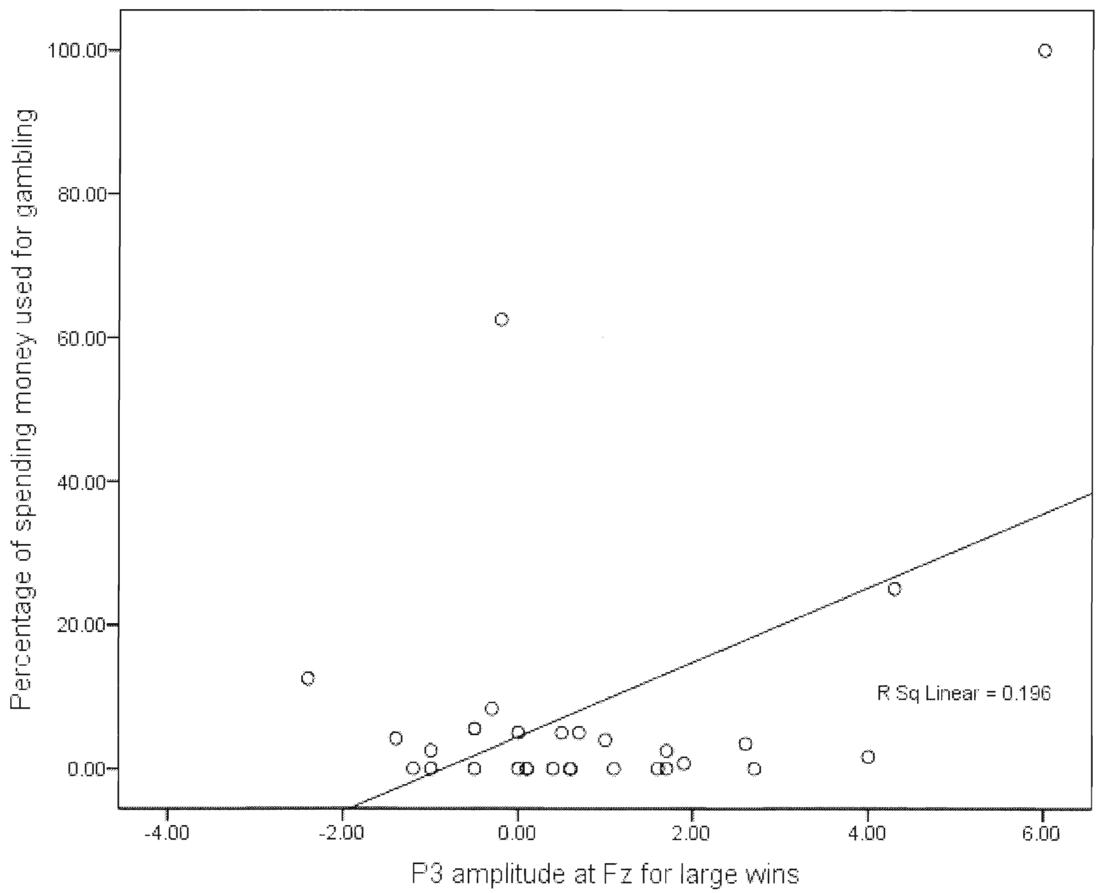


Figure 2.22

Scatter plots for the difference in P300 amplitude at Fz between win and loss feedback and percentage of spending money used for gambling

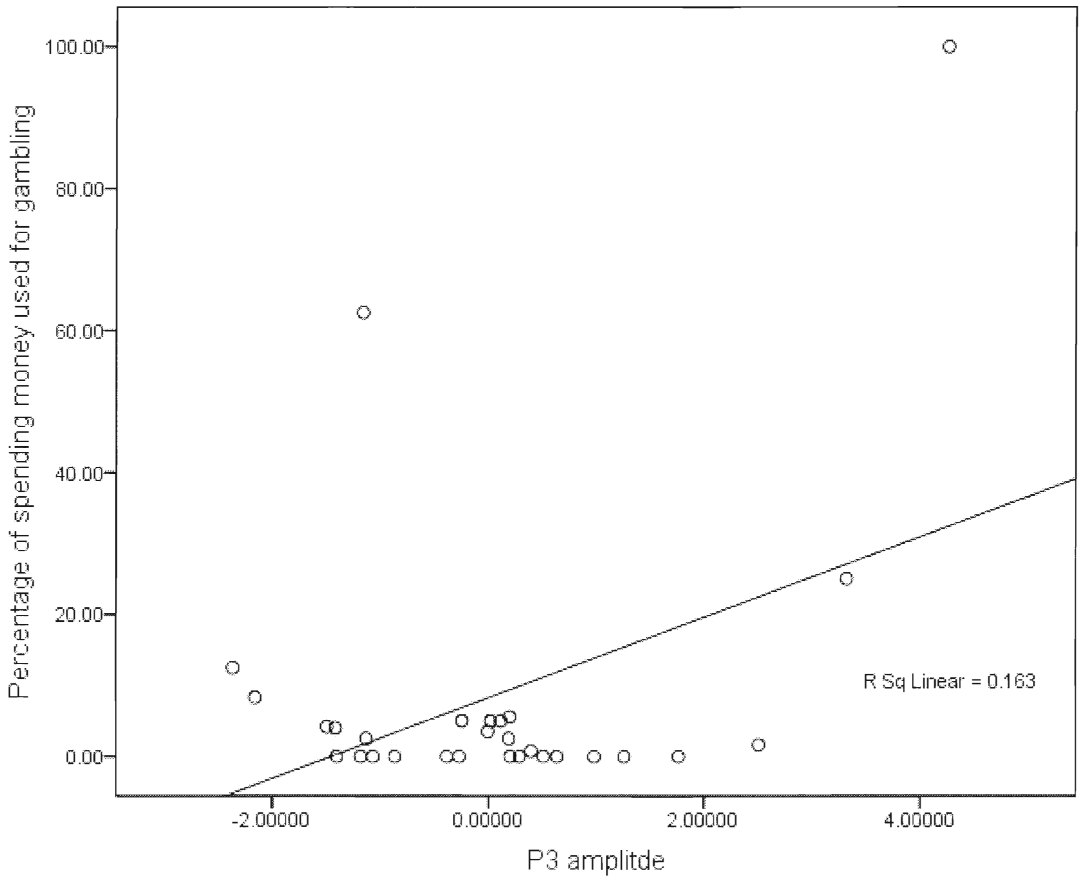


Figure 2.23

Scatter plots for the FRN amplitude at Cz for alternative cards of large losses and neuroticism scores

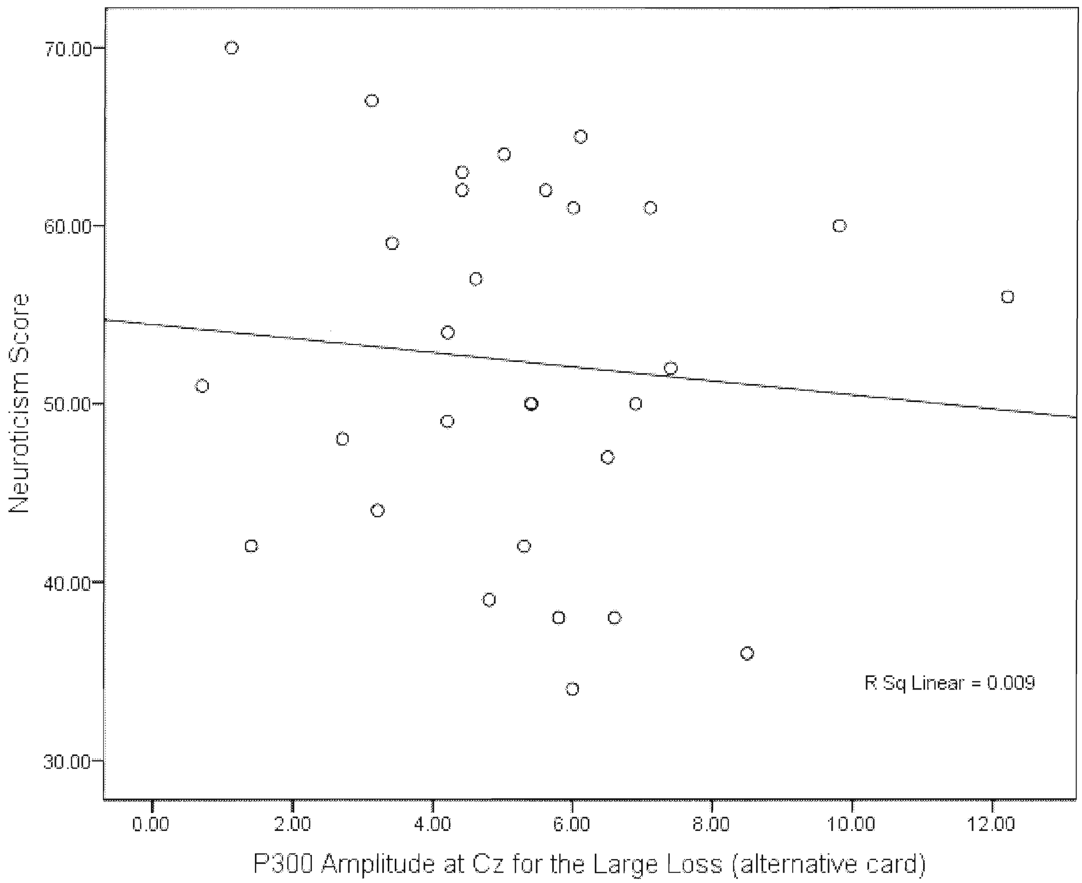


Figure 2.24

Scatter plots for the FRN amplitude at Cz for alternative cards of small wins and neuroticism scores

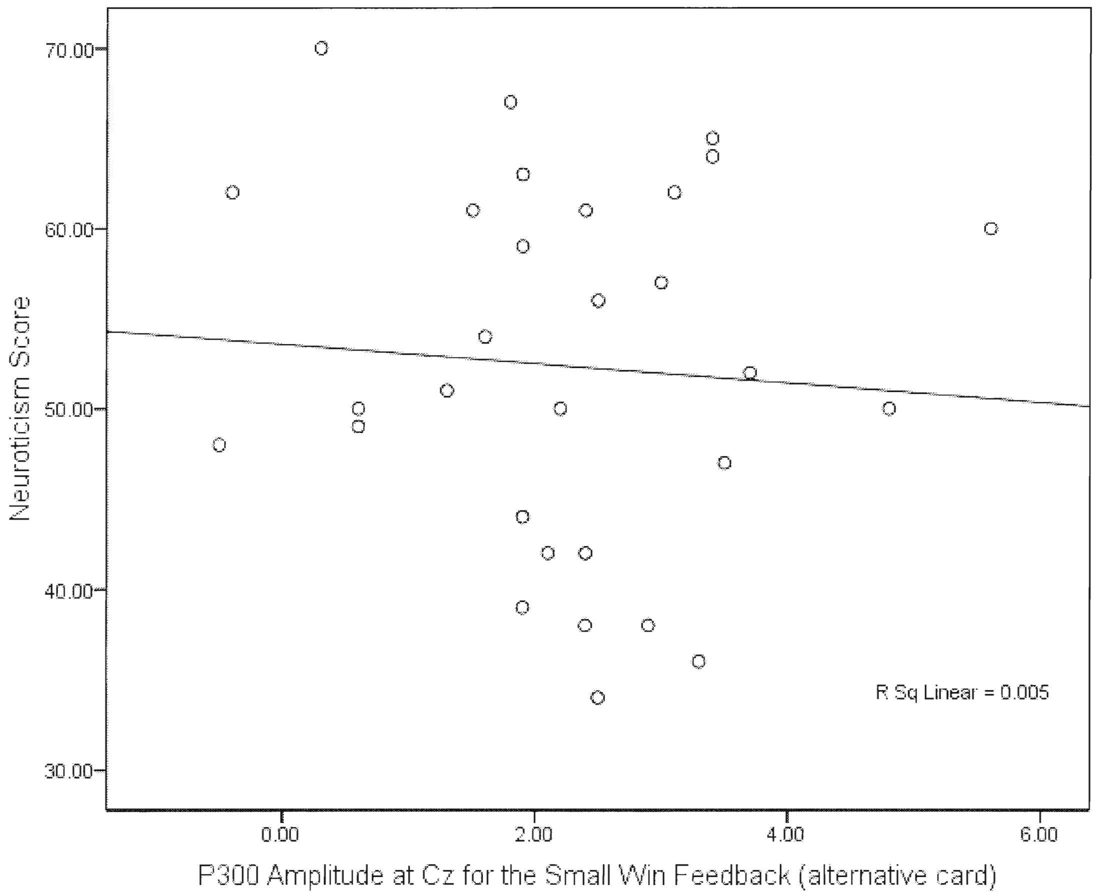


Figure 2.25

Scatter plots for the FRN amplitude at Cz for alternative cards of small loss and conscientiousness scores

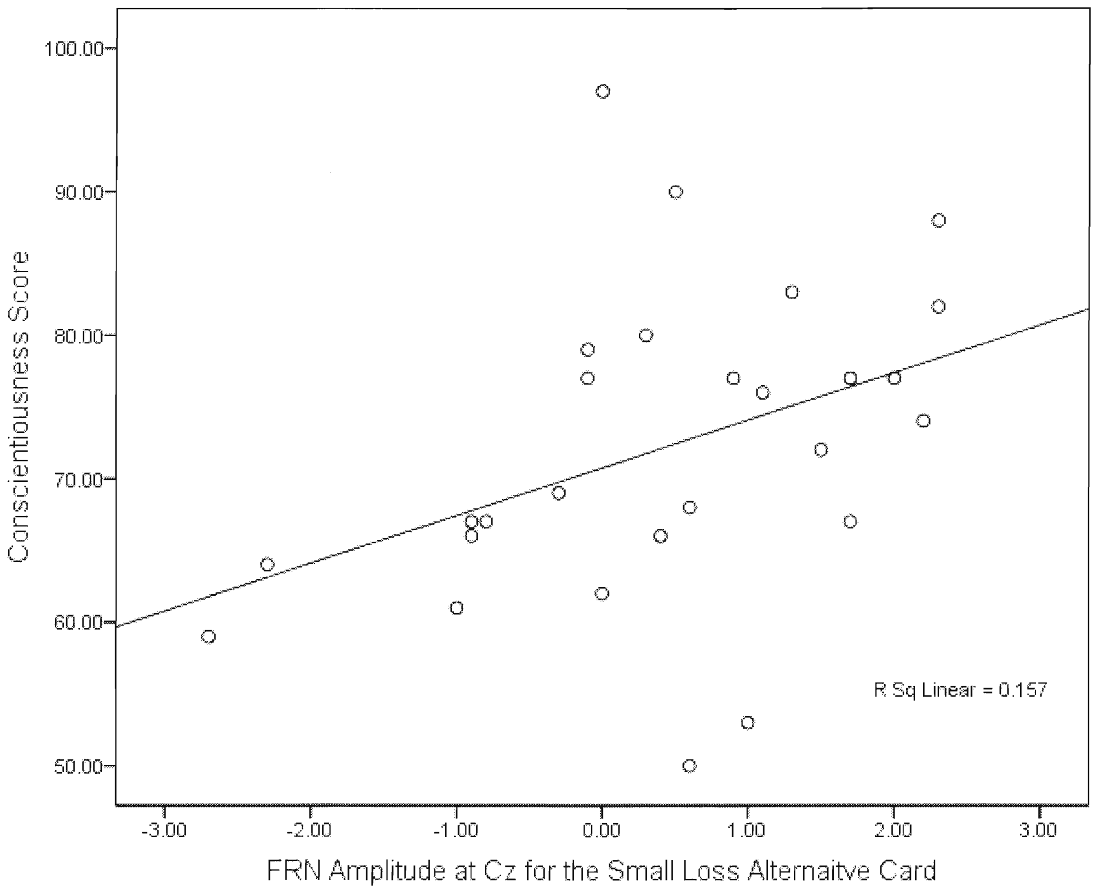


Figure 2.26

Scatter plots for the FRN amplitude at Cz for alternative cards of small wins and levels of reported cognitive distortions

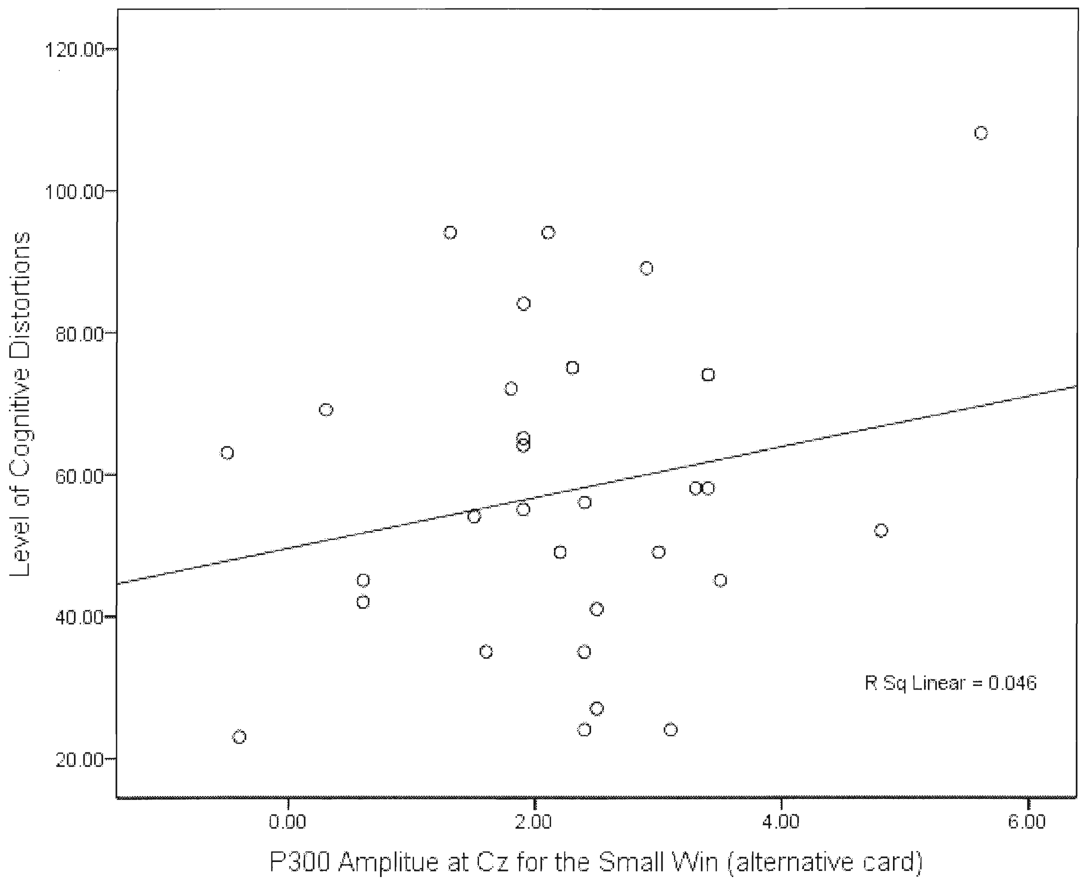


Figure 2.27

Scatter plots for the P300 amplitude at Cz for alternative cards of large wins and scores on the measure of obsessive compulsive characteristics

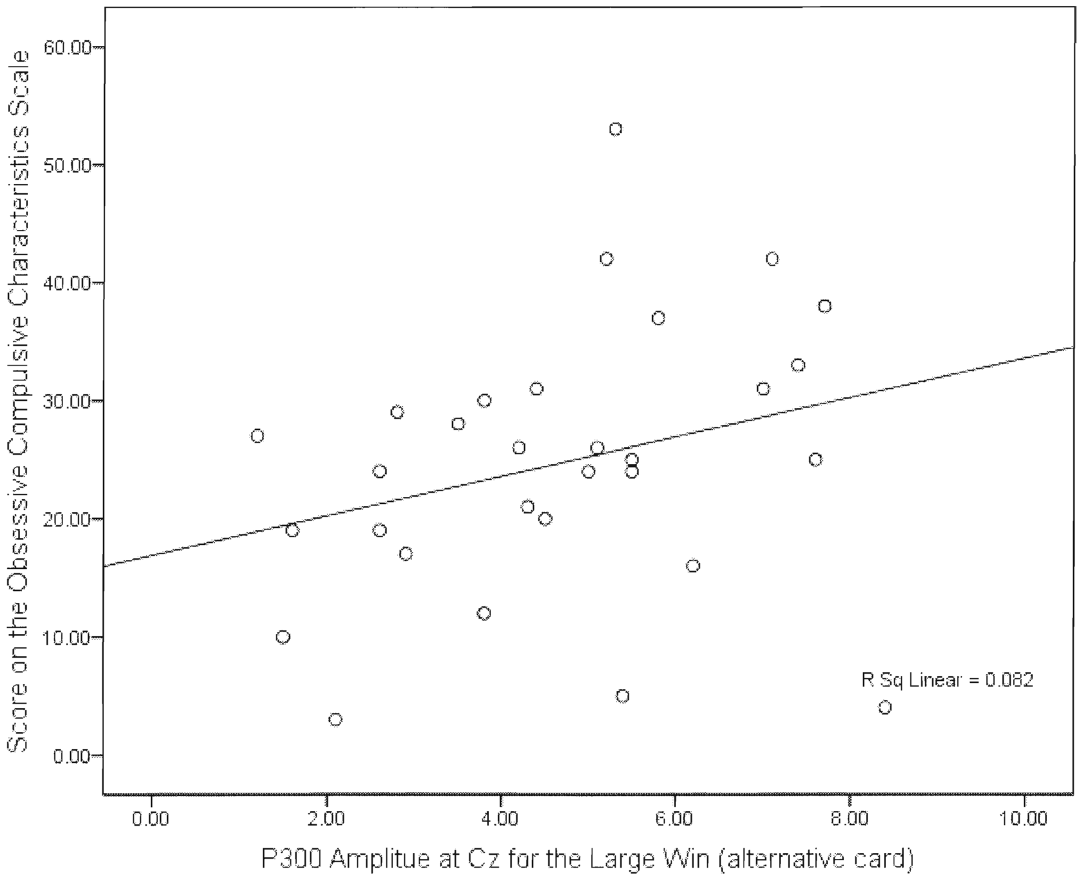


Figure 2.28

Scatter plots for the P300 amplitude at Cz for alternative cards of small wins and scores on the measure of obsessive compulsive characteristics

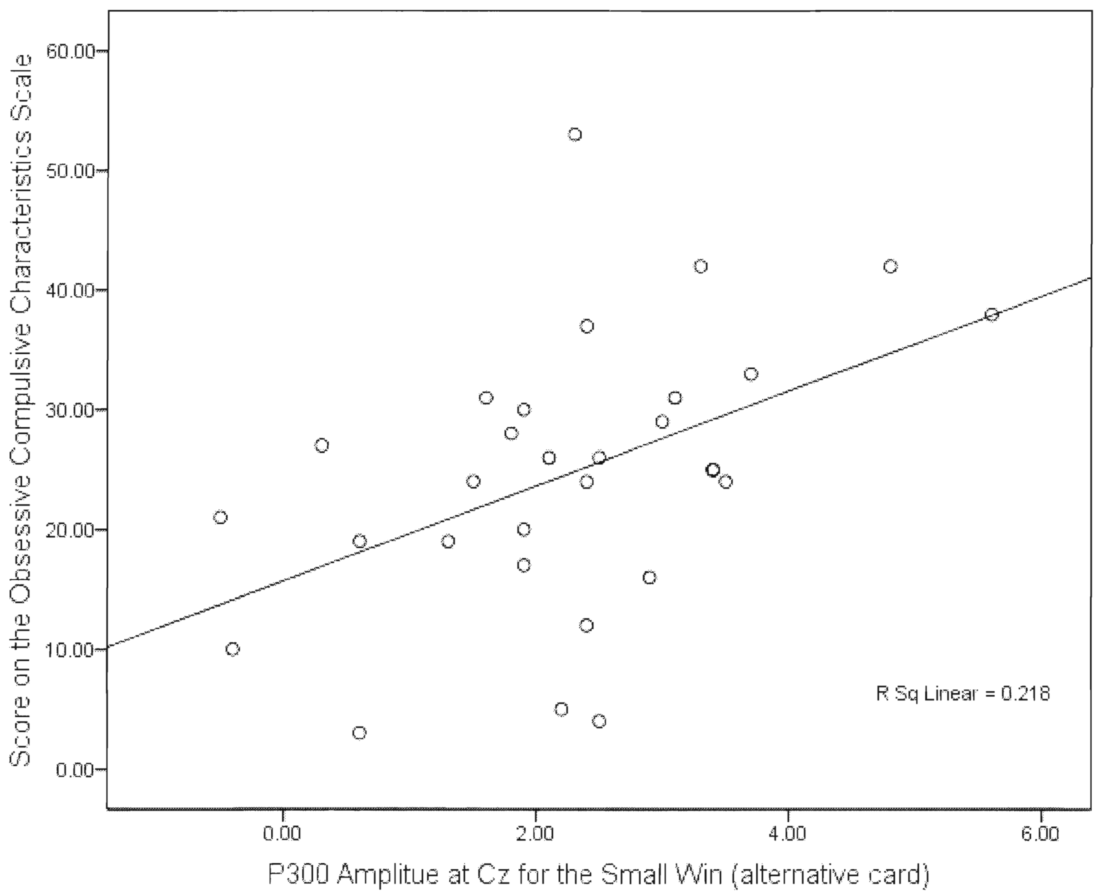


Figure 2.29

Scatter plots for the FRN amplitude at Cz for the win joy condition and conscientiousness scores

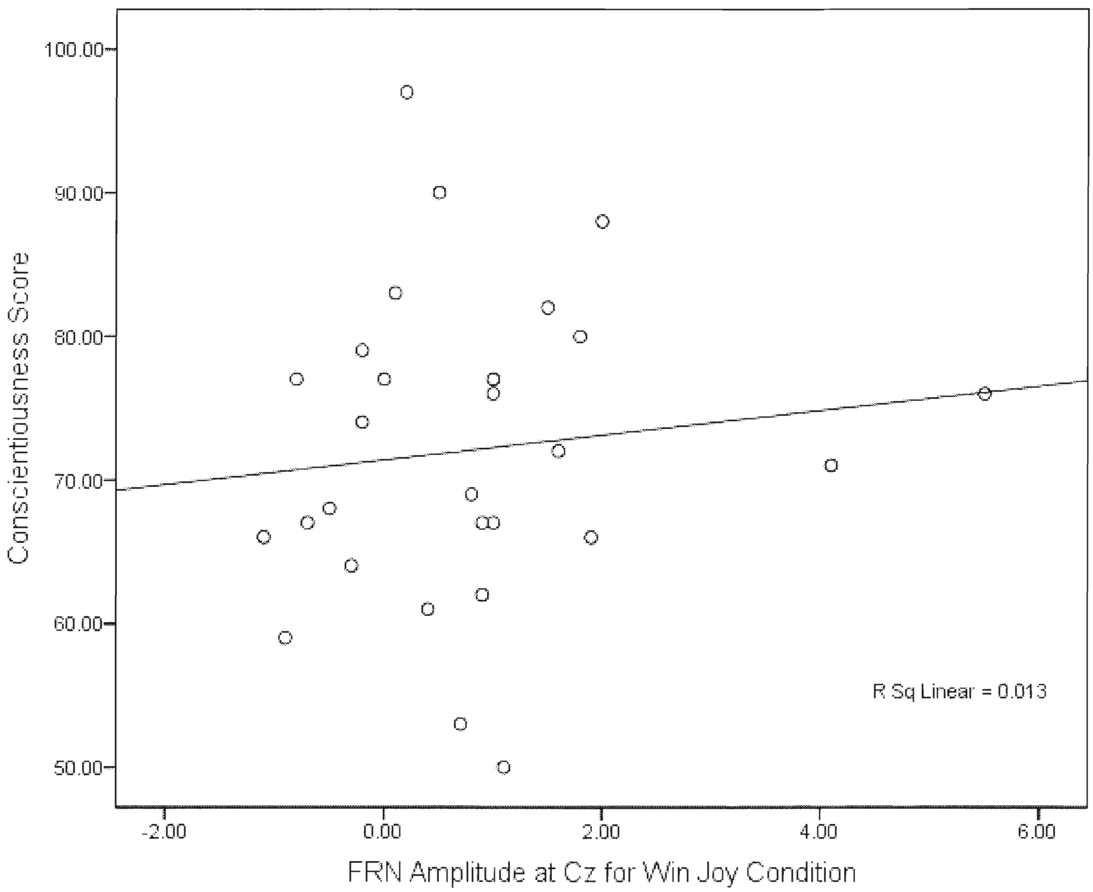


Figure 2.30

Scatter plots for the P300 amplitude at Cz for the win joy condition and scores on the measure of obsessive compulsive characteristics

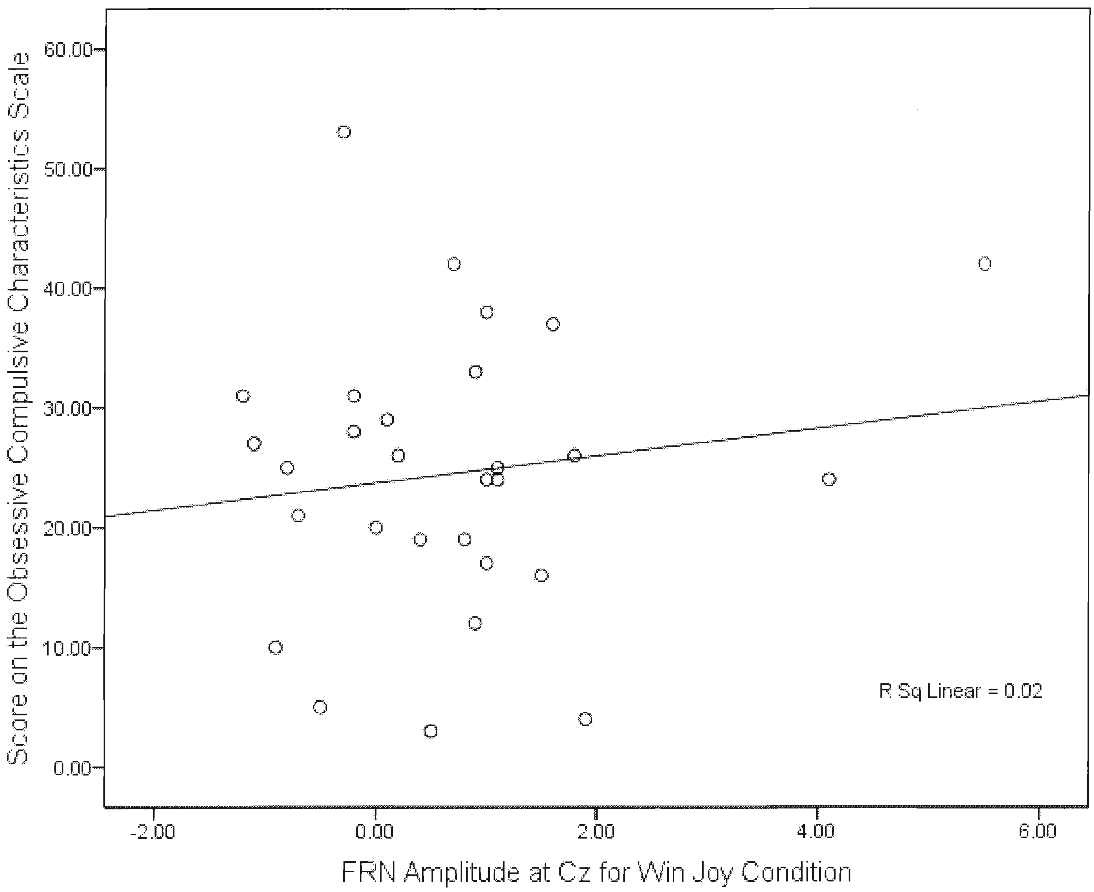


Figure 2.31

Scatter plots for the P300 amplitude at Cz for the lose regret condition and scores on the measure of obsessive compulsive characteristics

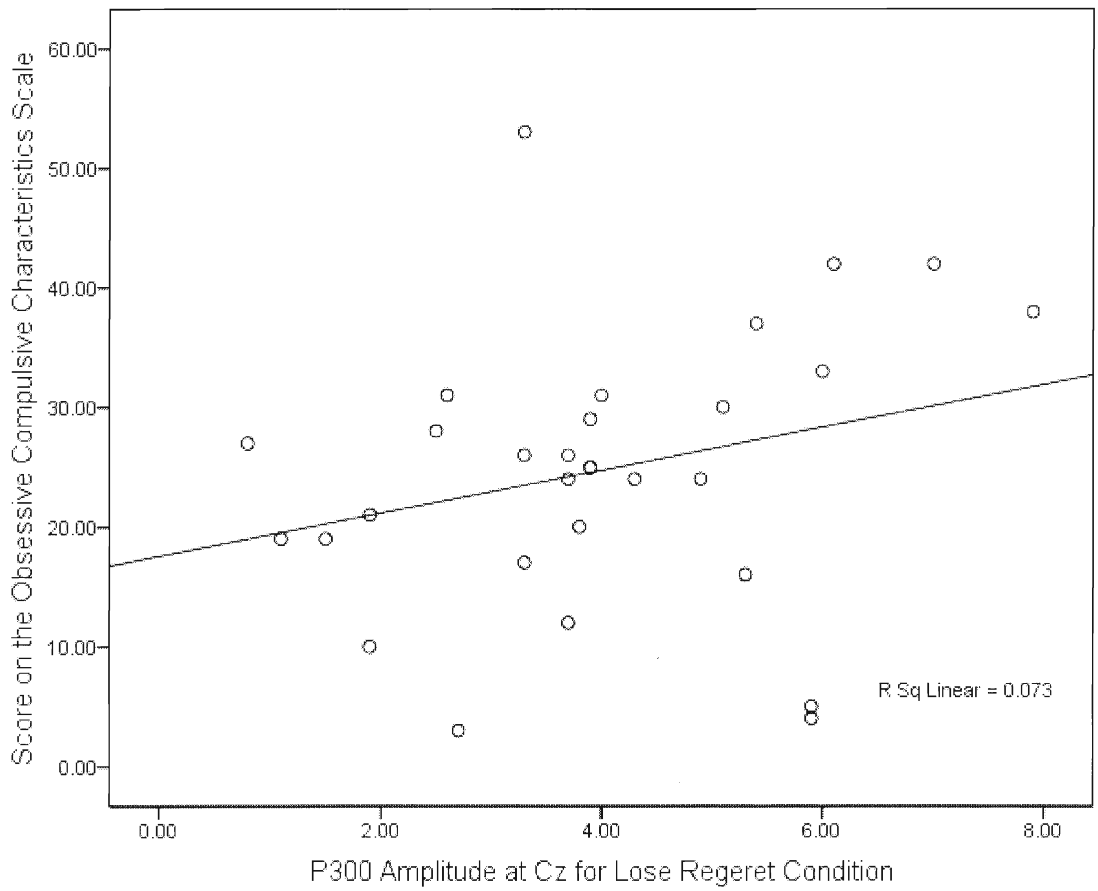


Figure 2.32

Scatter plots for the difference in FRN amplitude at Cz between win and loss alternative cards and conscientiousness scores

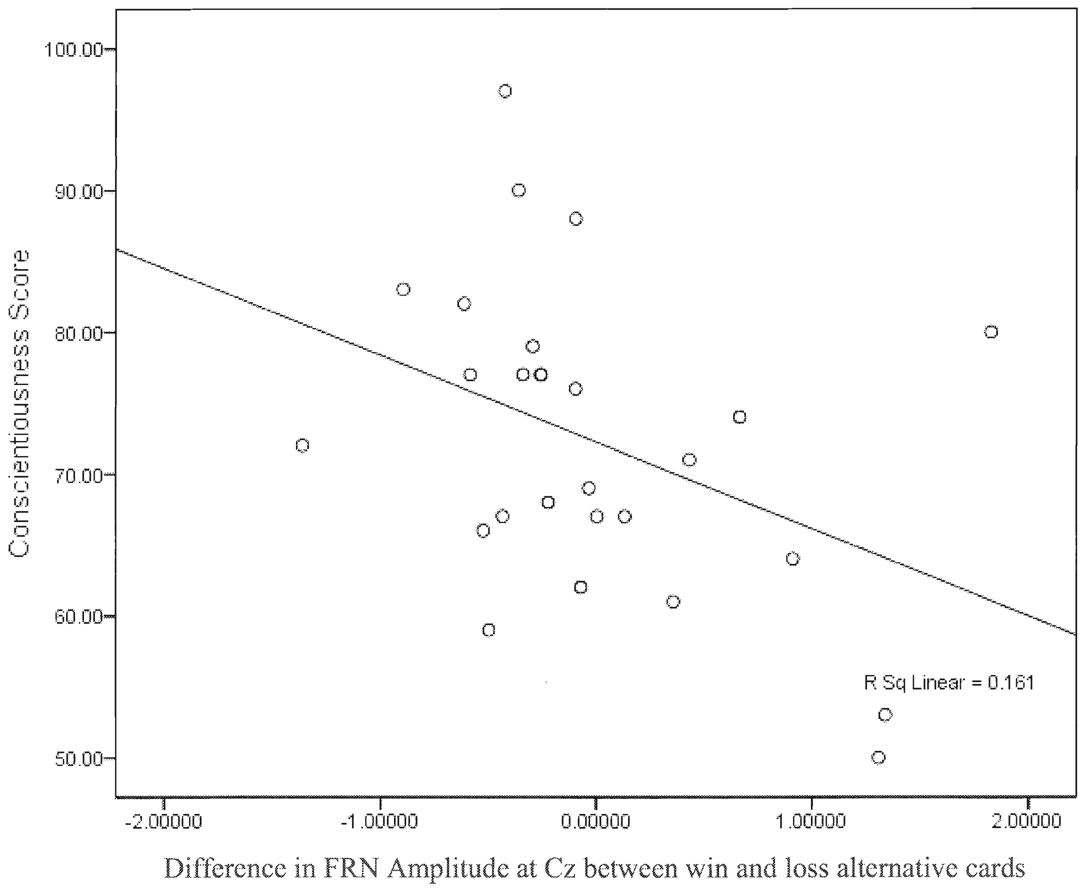


Figure 2.33

Scatter plots for the difference in P300 amplitude at Cz between win and loss alternative cards and scores on the measure of obsessive compulsive characteristics

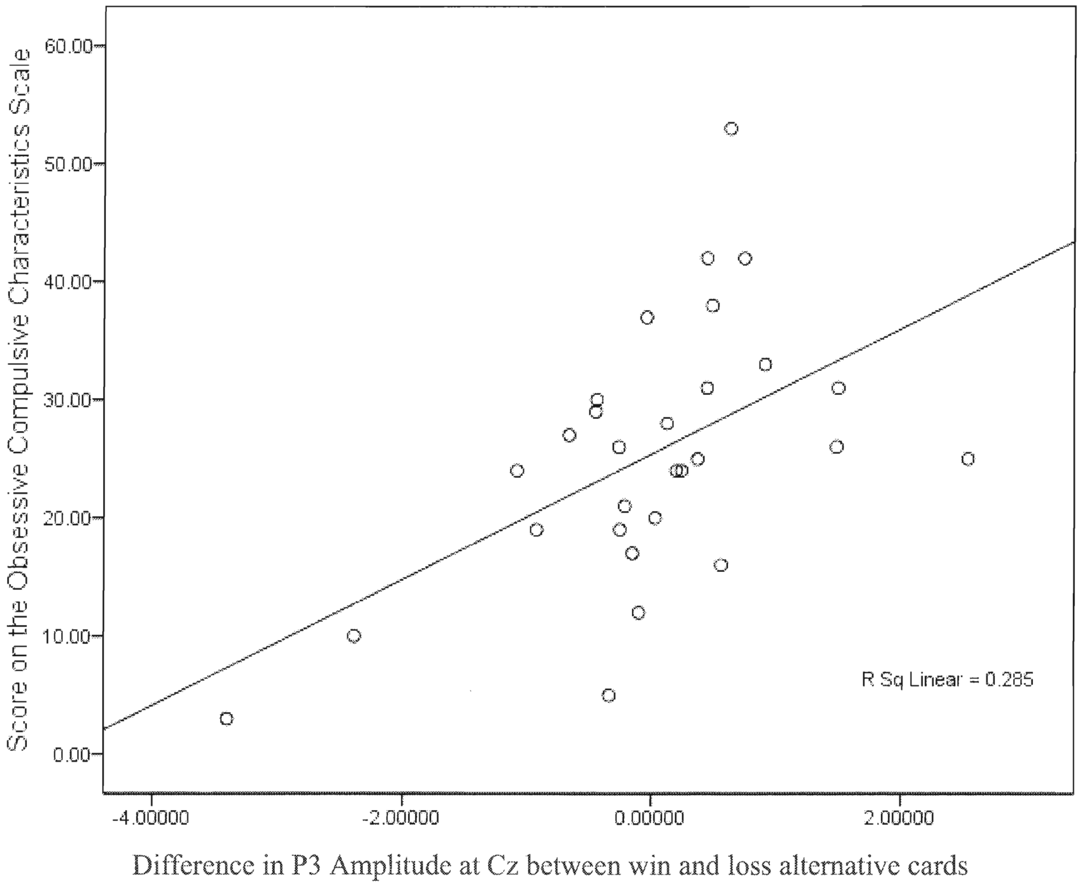


Figure 2.34

Scatter plots for the difference in P300 amplitude at Cz between win and loss alternative cards and levels of reported cognitive distortions

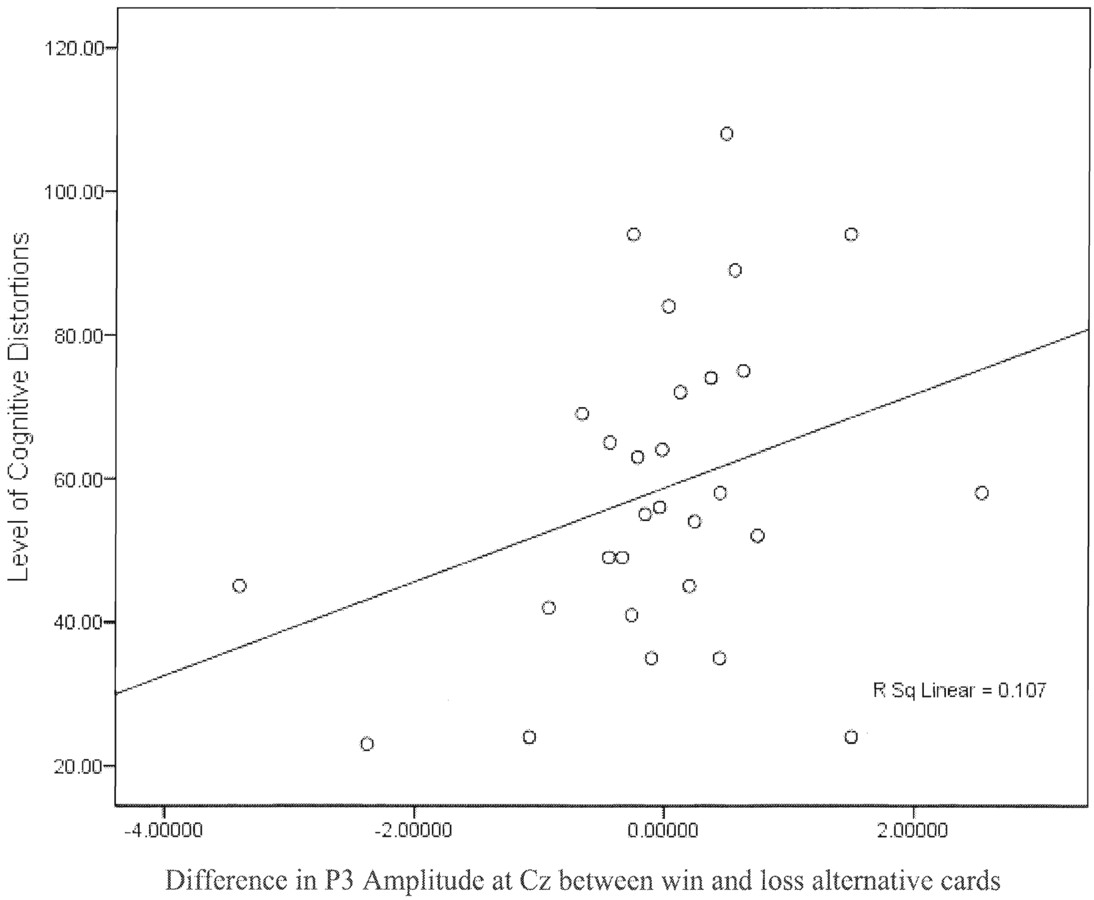


Figure 2.35

Scatter plots for the difference in P300 amplitude at Cz between win joy and loss regret conditions and sensitivity to reward scores

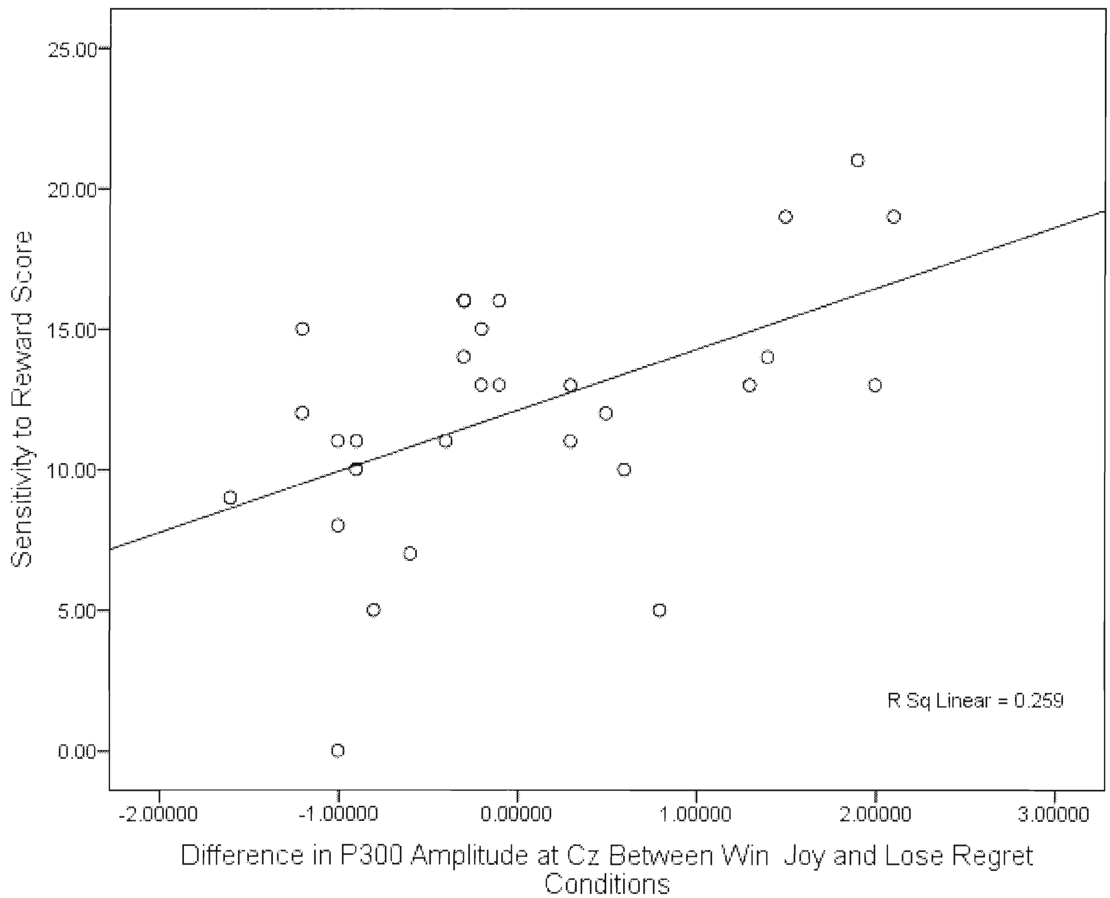


Figure 2.36

Scatter plots for the P300 amplitude at Cz for alternative cards of large losses and percentage of spending money used for gambling

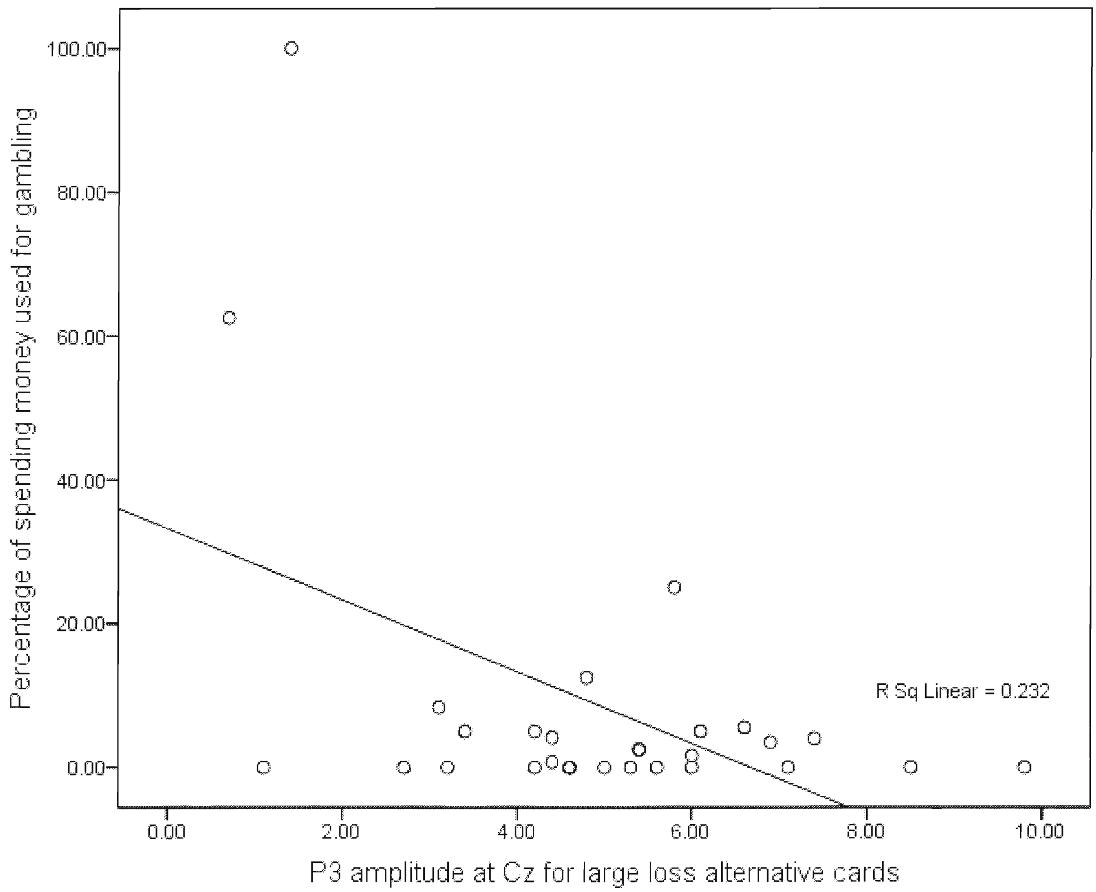


Figure 2.37

Scatter plots for the FRN amplitude at Cz for loss regret condition and percentage of spending money used for gambling

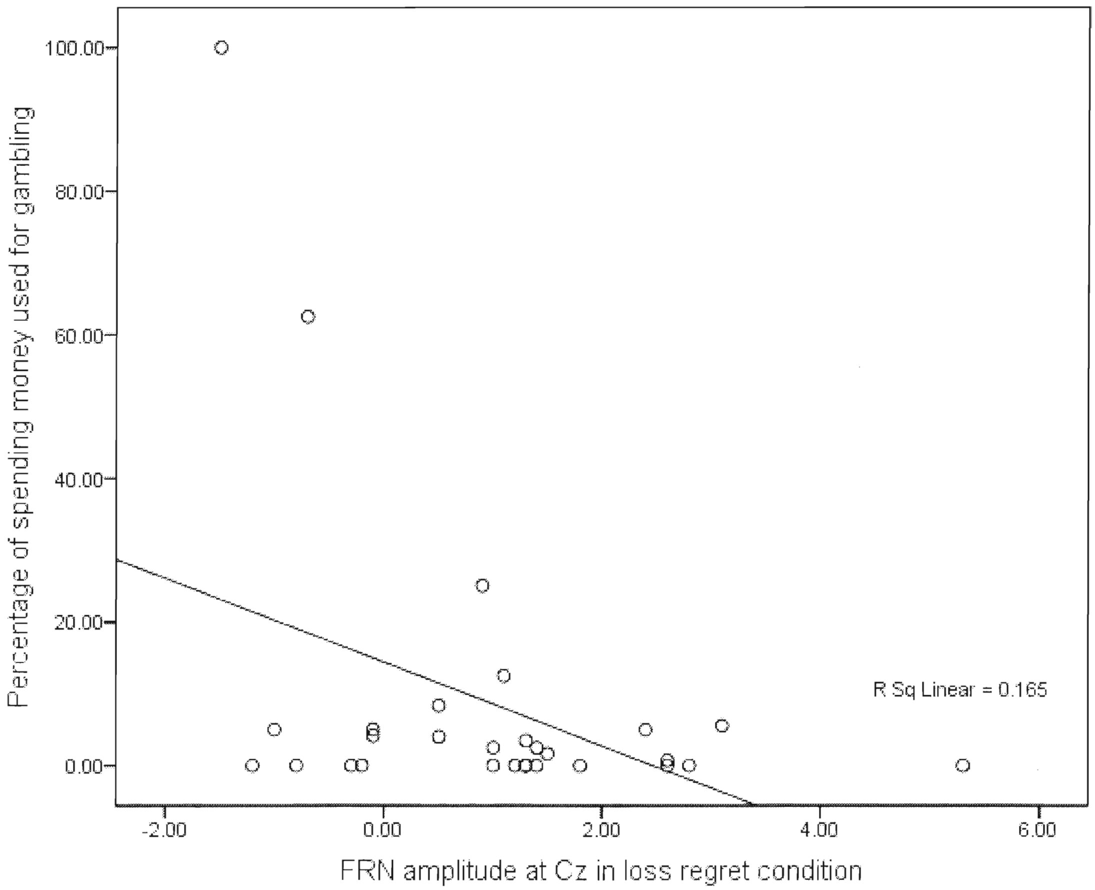


Figure 3.1

The sequence of events during a trial of the simple response task.

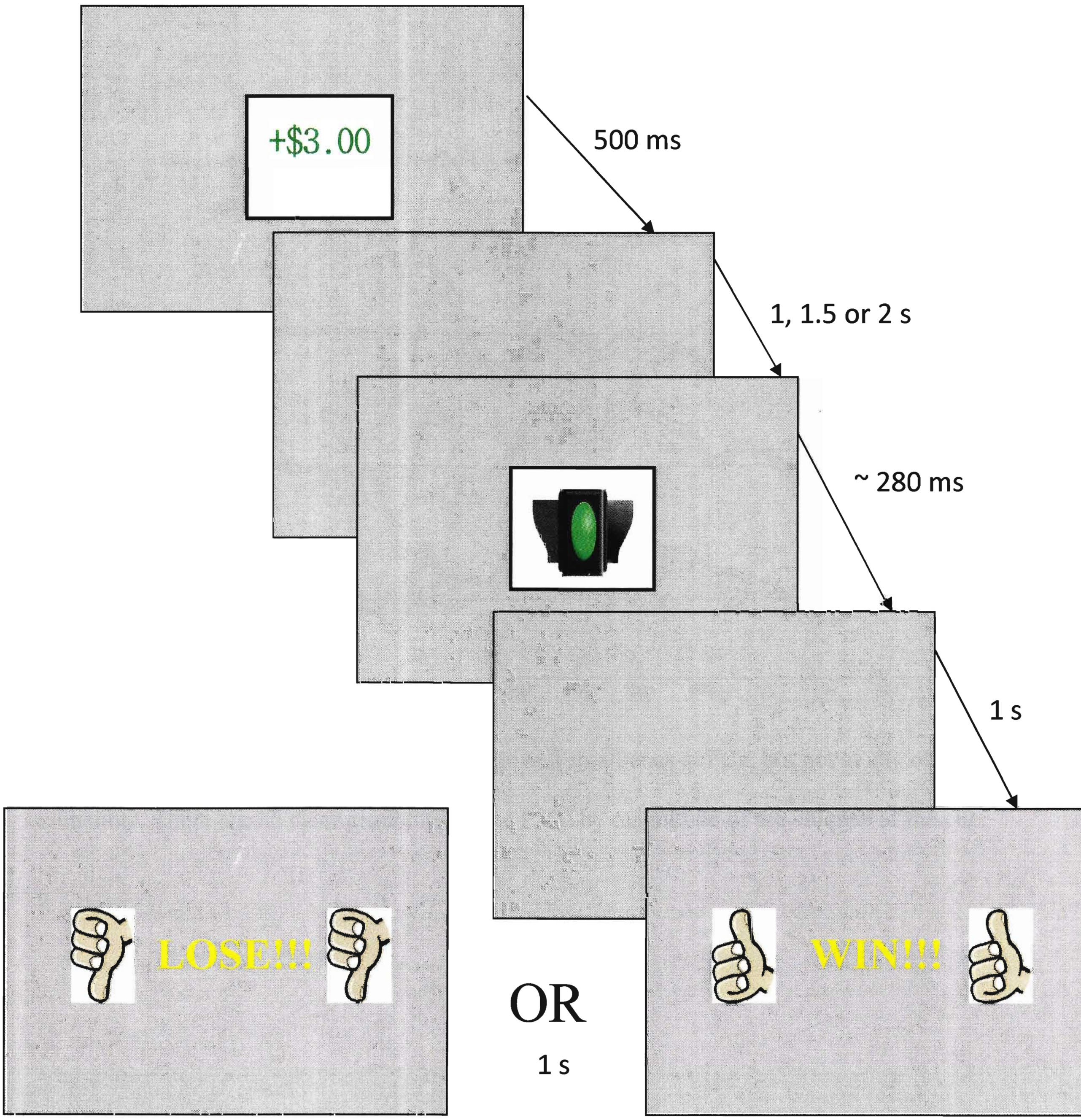
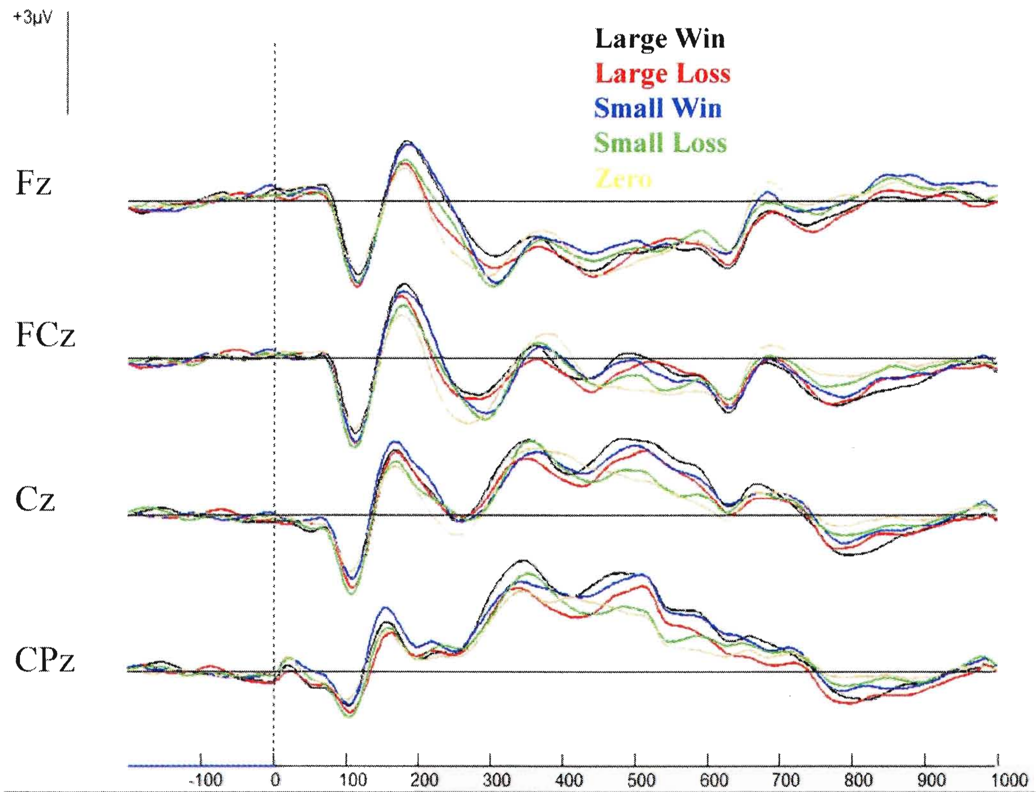


Figure 3.2

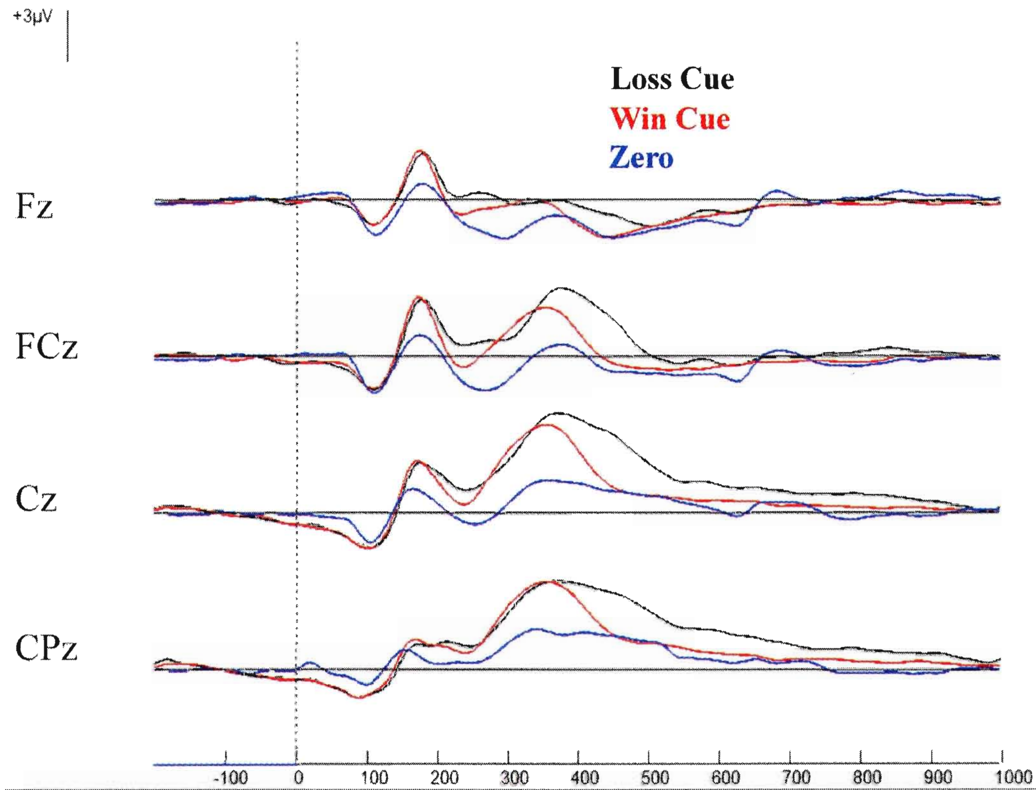
Stimulus locked overlay of the averaged ERP waveforms for the five types of cues.



Note. The FRN differentiates between large and small cues at FCz, but not at any other channel. There are no clear groupings of the P300 by magnitude or the valence of the cue.

Figure 3.3

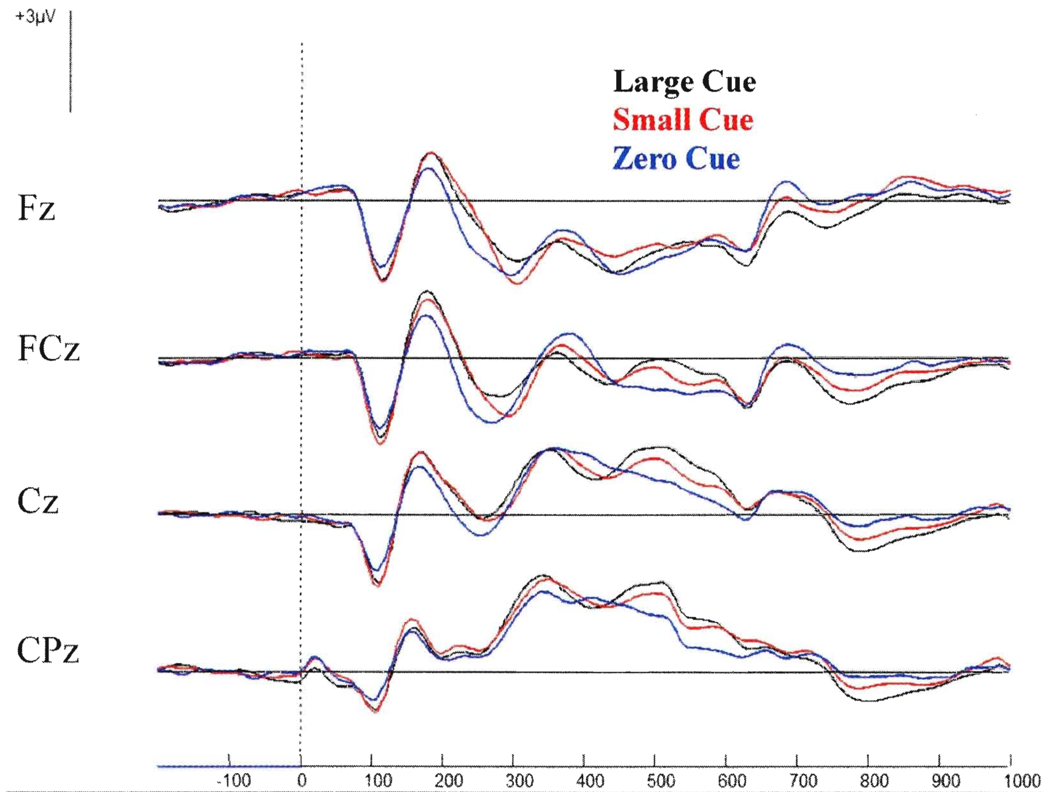
Stimulus locked overlay of the ERP waveforms to the cue, averaged over trials based on the valence of the cue.



Note. Wins and losses are not clearly differentiated at all the FRN, however the losses are slightly more negative than the wins. Similar observations can be made for the P300 amplitude, where the differentiation is not clear at the peaks but wins are consistently slightly more positive.

Figure 3.4

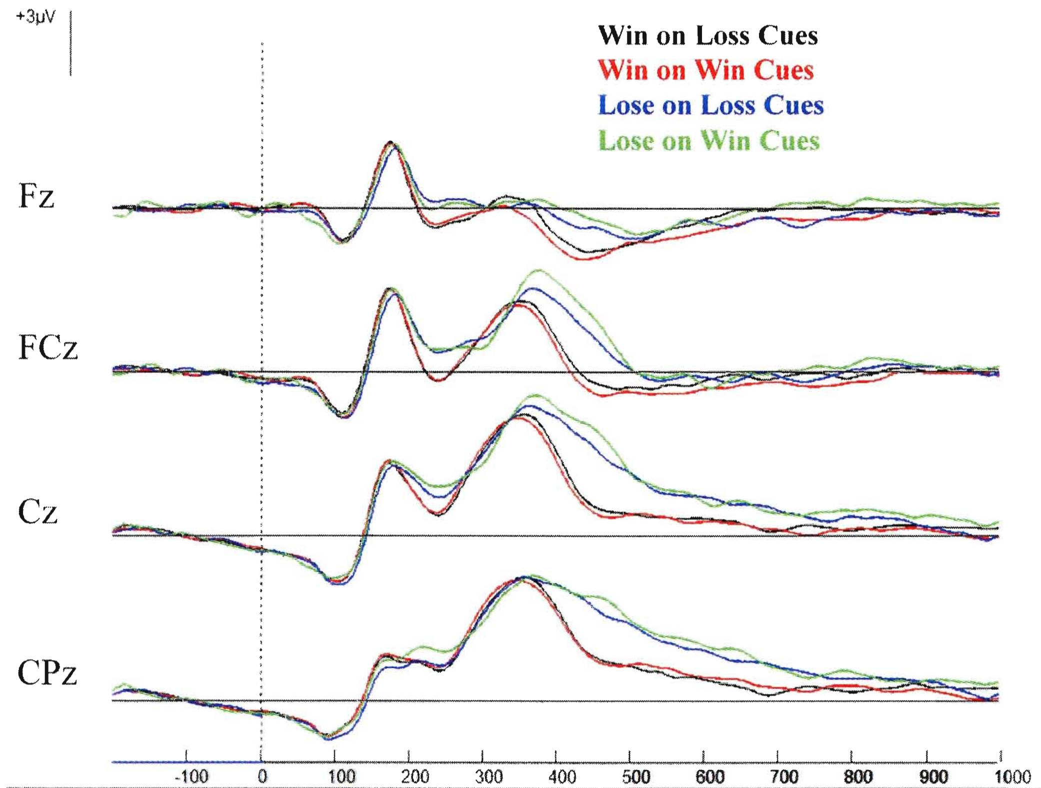
Stimulus locked overlay of the ERP waveforms to the cues, averaged over trials based on the magnitude of the cue.



Note. Large cues were associated with smaller FRN amplitude as well as smaller P300 amplitude. On the other hand, zero cues elicited larger FRN and P300 amplitudes.

Figure 3.5

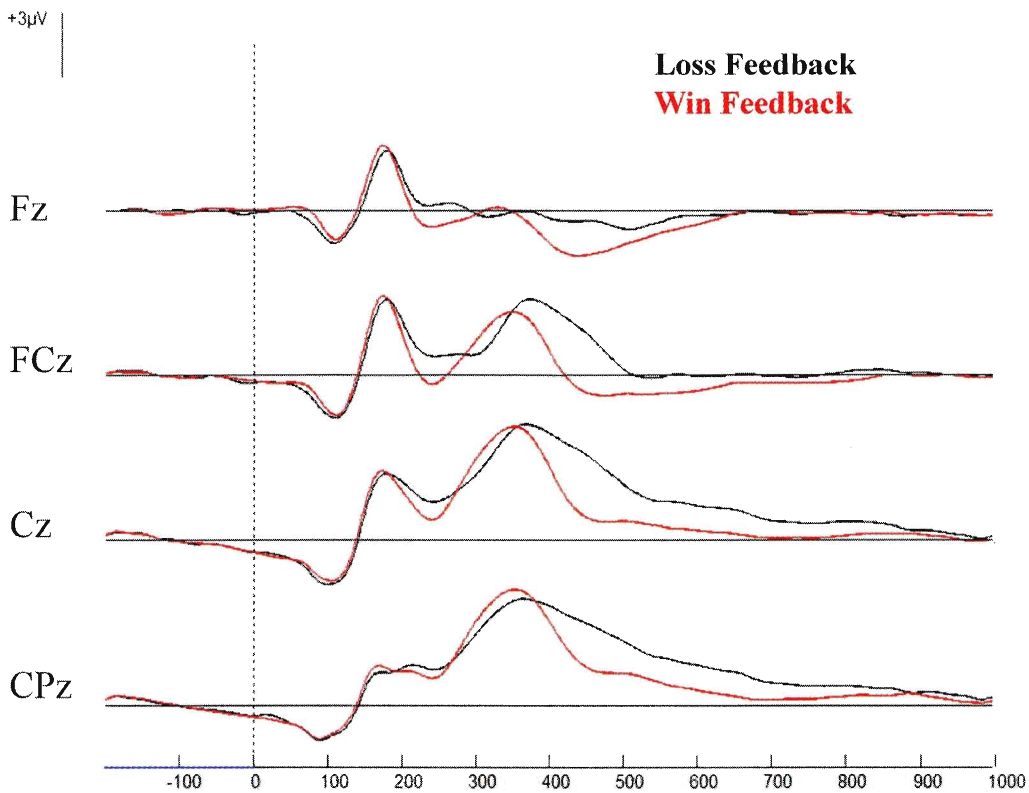
Stimulus locked overlay of the averaged ERP waveforms for the feedback on the four trials.



Note. The feedback to the loss cues produced smaller FRN amplitude and larger P300 amplitude, both of which peak later than the feedback to the win cues.

Figure 3.6

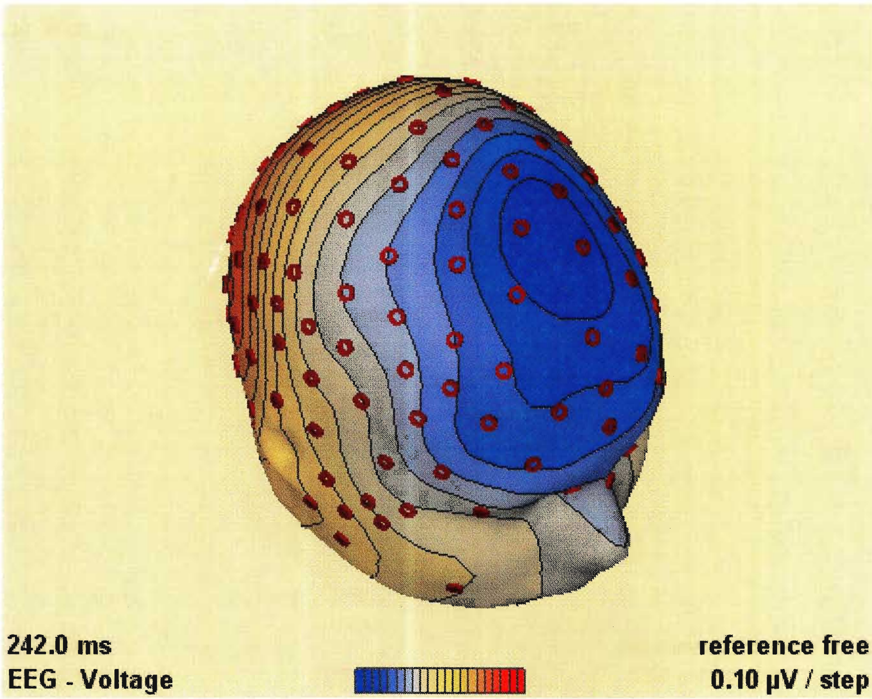
Stimulus locked overlay of the ERP waveforms, averaged based on the valence of the feedback.



Note Loss feedback is associated with smaller FRN amplitude, larger P300 amplitude, as well as later peaks for the both components.

Figure 3.7

Grand average topographical map of the difference in the FRN amplitude between win and loss feedback in the simple response task (Study 2).

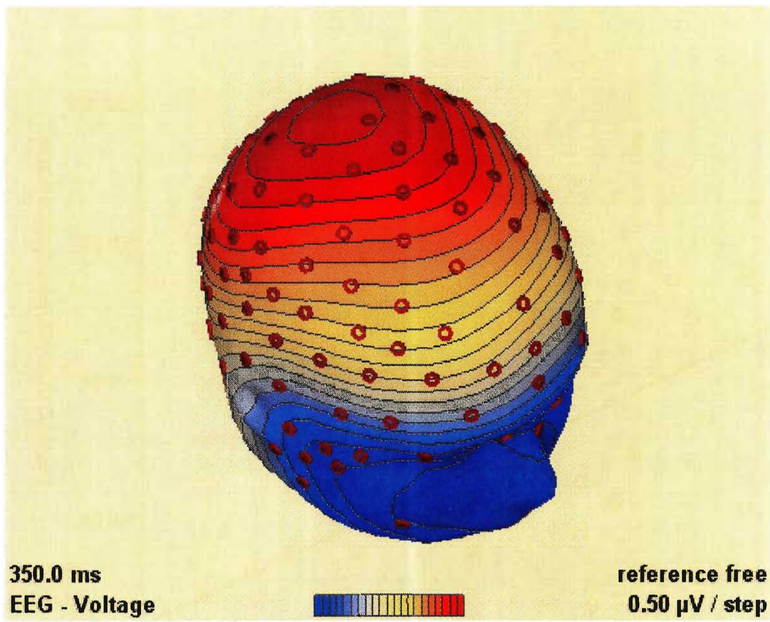


Note. Losses elicited smaller FRN amplitude than wins, in contrast to the results observed in the pure gambling task.

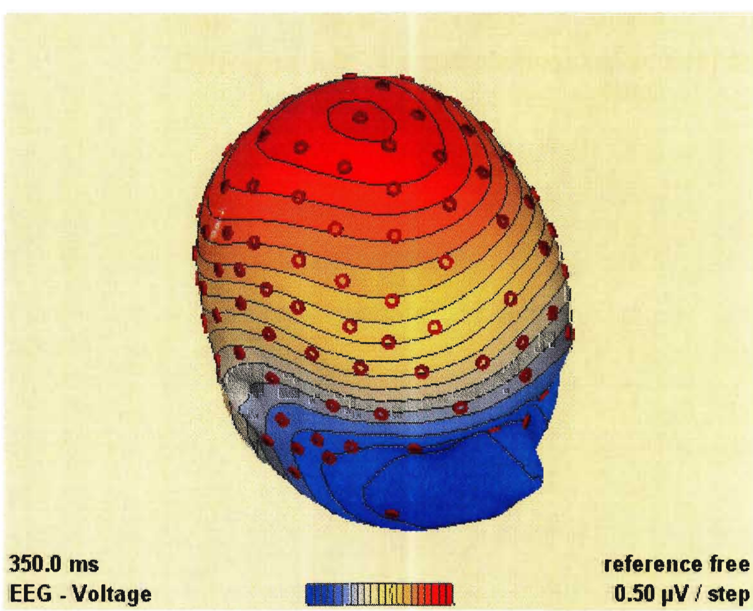
Figure 3.8

Grand average topographical map of the P3 for the win and loss feedback conditions of the simple response task (Study 2).

a) Win



b) Loss



Note. Loss feedback elicited slightly larger and more prolonged P3components.

Figure 3.9

Scatter plots for the difference in the MFN amplitude at Fz between the large and small cues and levels of cognitive distortions.

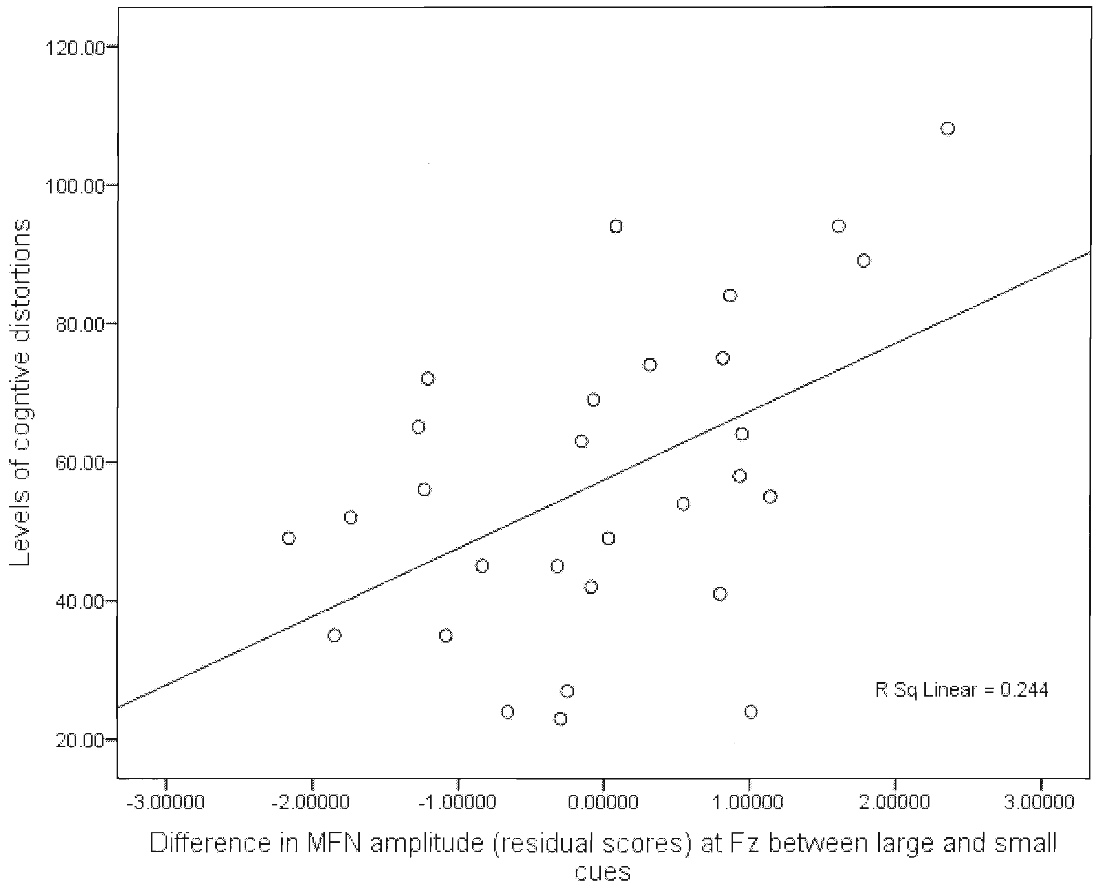


Figure 3.10

Scatter plots for the difference in MFN amplitude at Fz between large and small cues and conscientiousness scores.

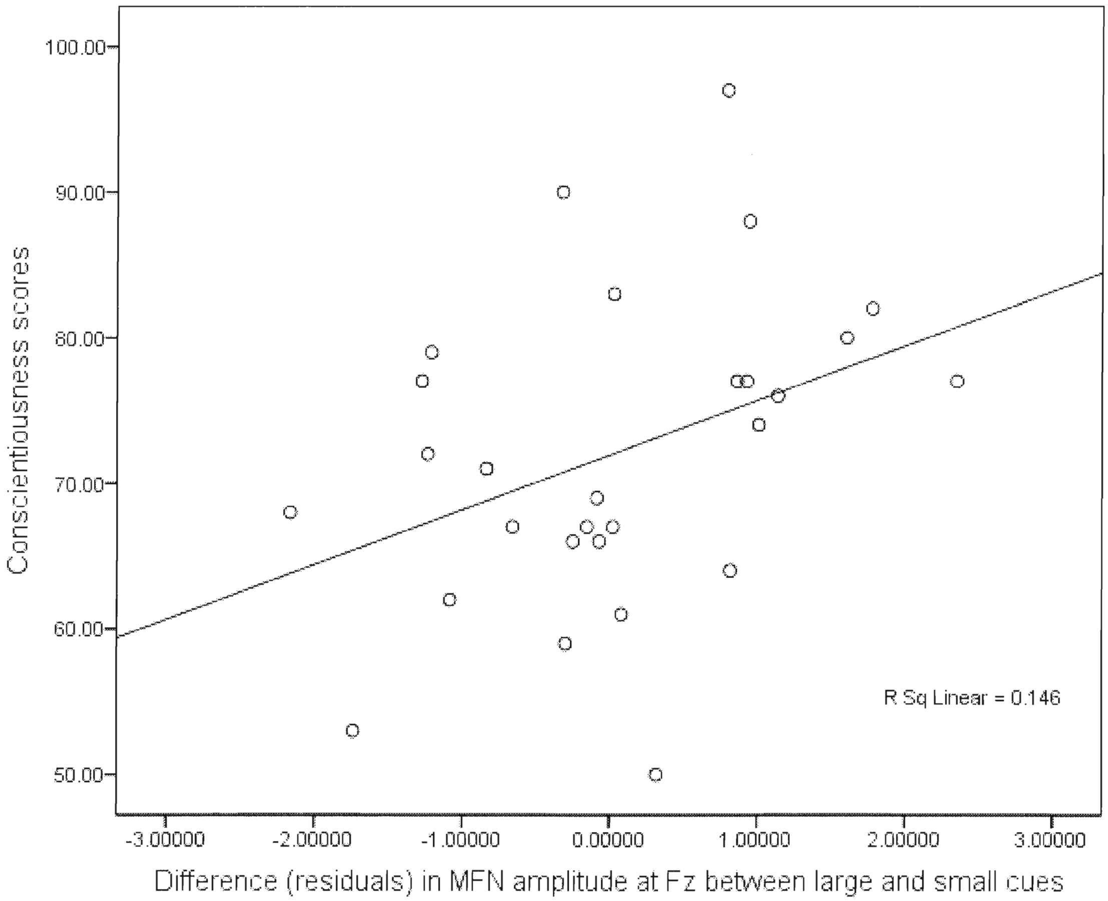


Figure 3.11

Scatter plots for the difference in P300 amplitude at CPz between large and small cues and neuroticism scores.

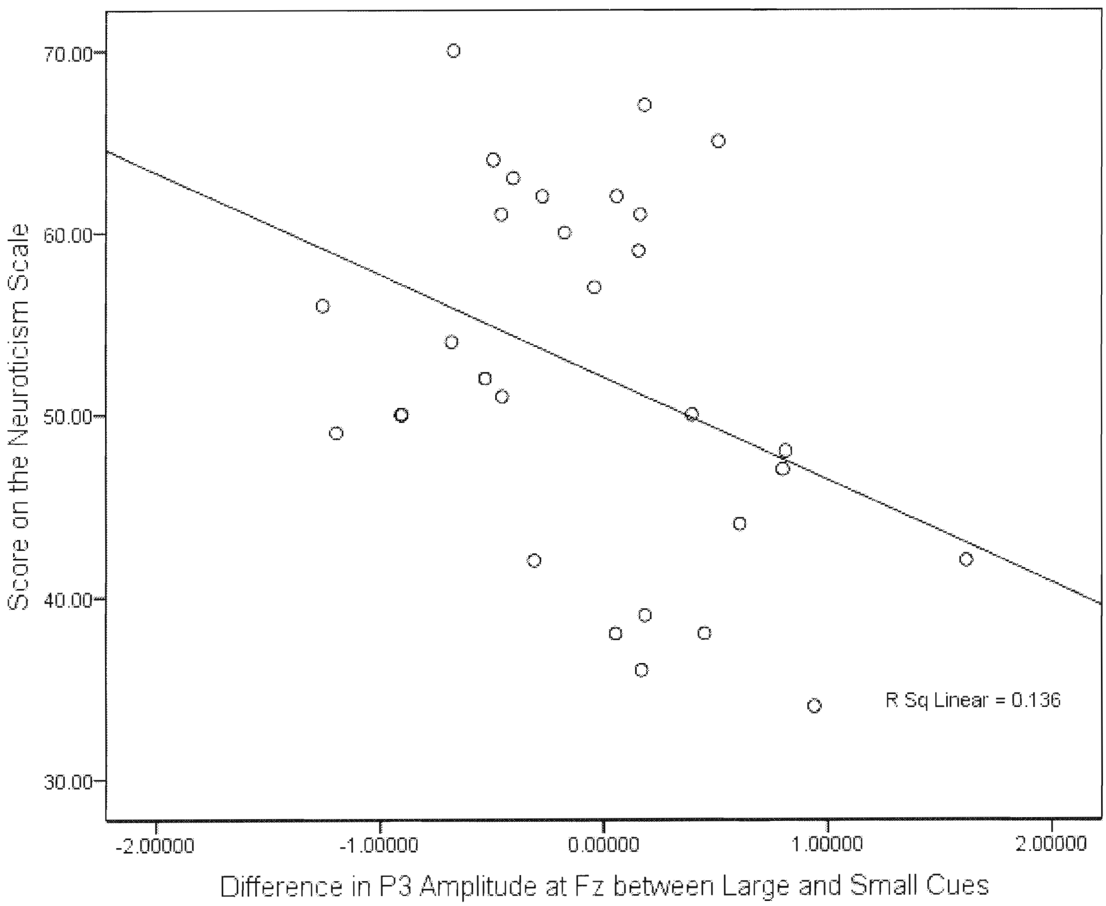


Figure 3.12

Scatter plots for the difference in the MFN amplitude at Fz between win and loss cues and levels of obsessive compulsive characteristics reported.

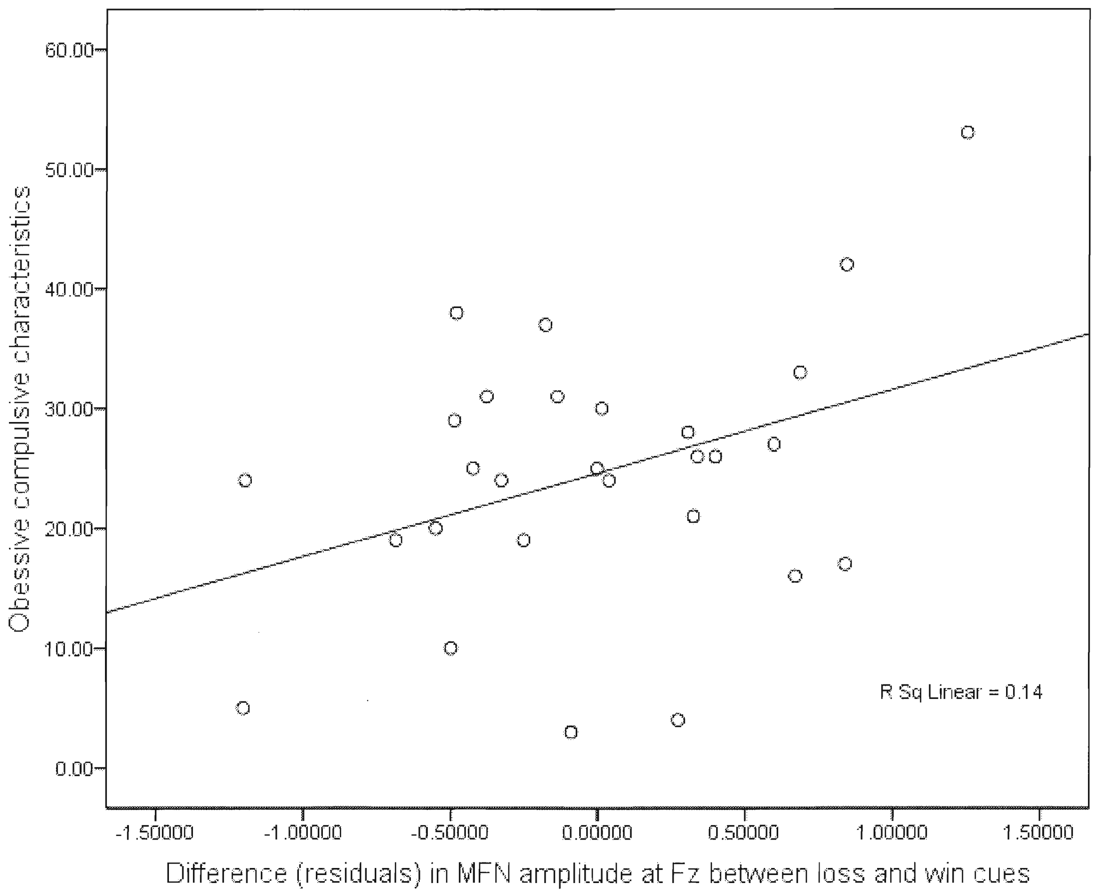


Figure 3.13

Scatter plots for the difference in the P3 amplitude at CPz between large and small cues and sensitivity to reward scores.

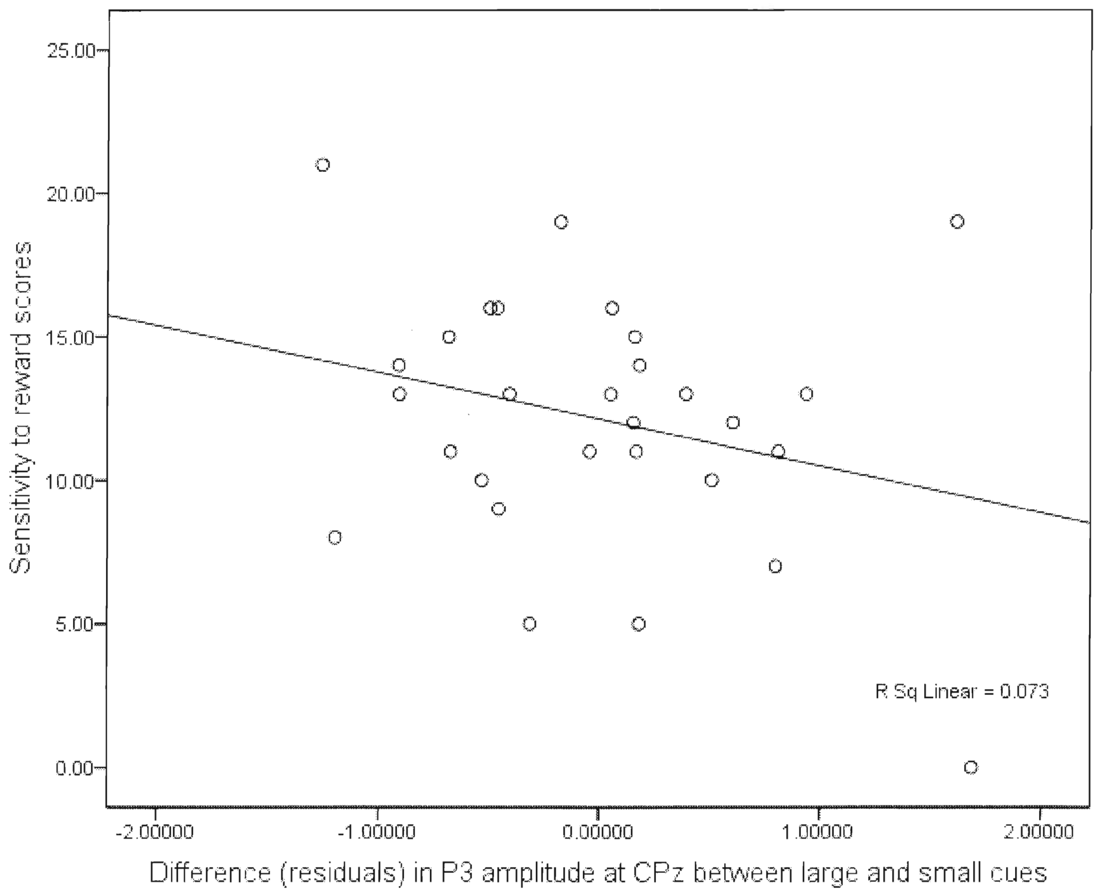


Figure 3.14

Scatter plots for the MFN amplitude at Fz during the small win cues and harm avoidance scores.

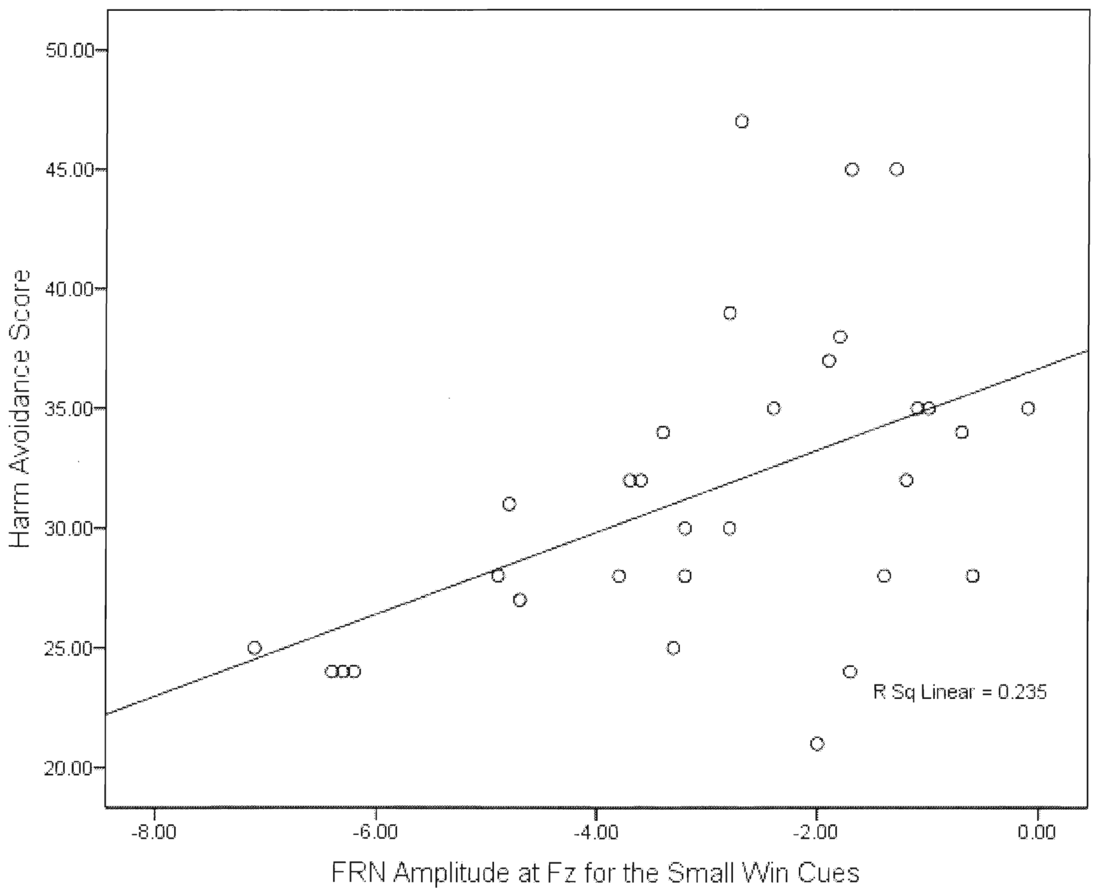


Figure 3.15

Scatter plots for the MFN amplitude at Fz during the small loss cues and harm avoidance scores.

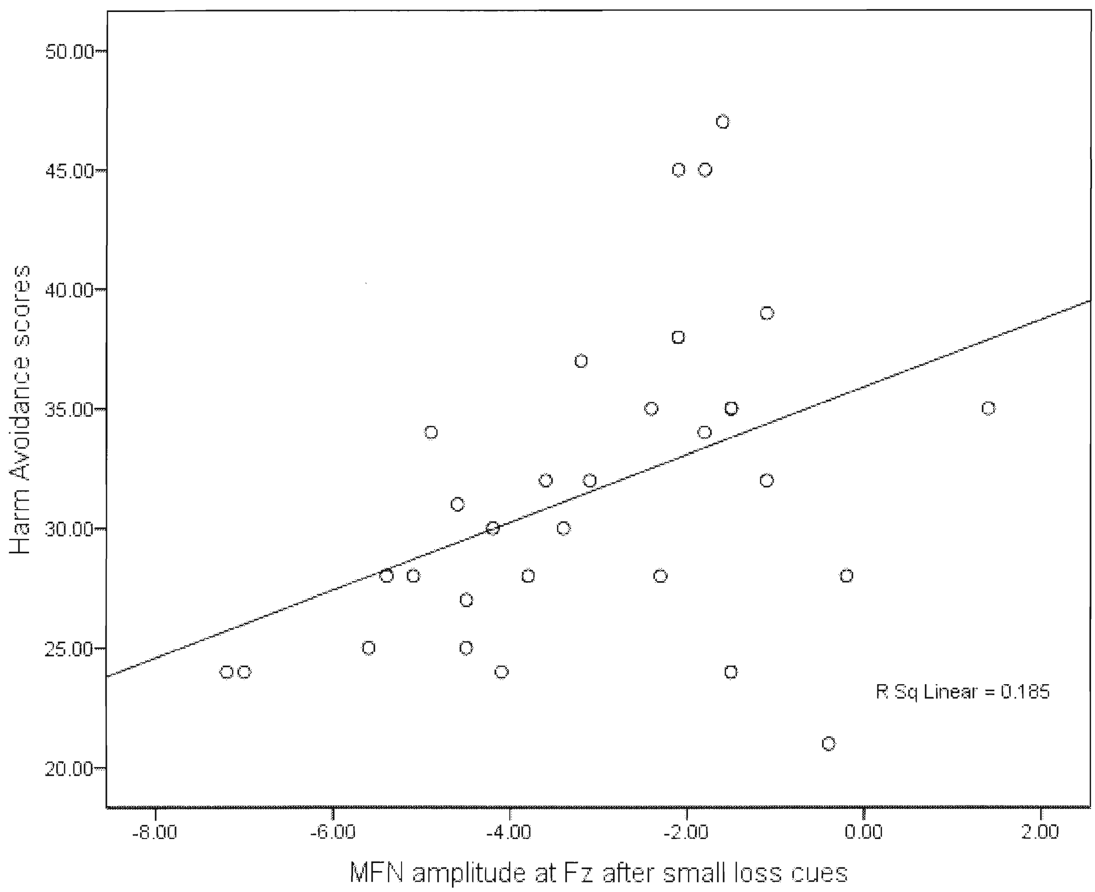


Figure 3.16

Scatter plots for the MFN amplitude at Fz during the large win cues and harm avoidance scores.

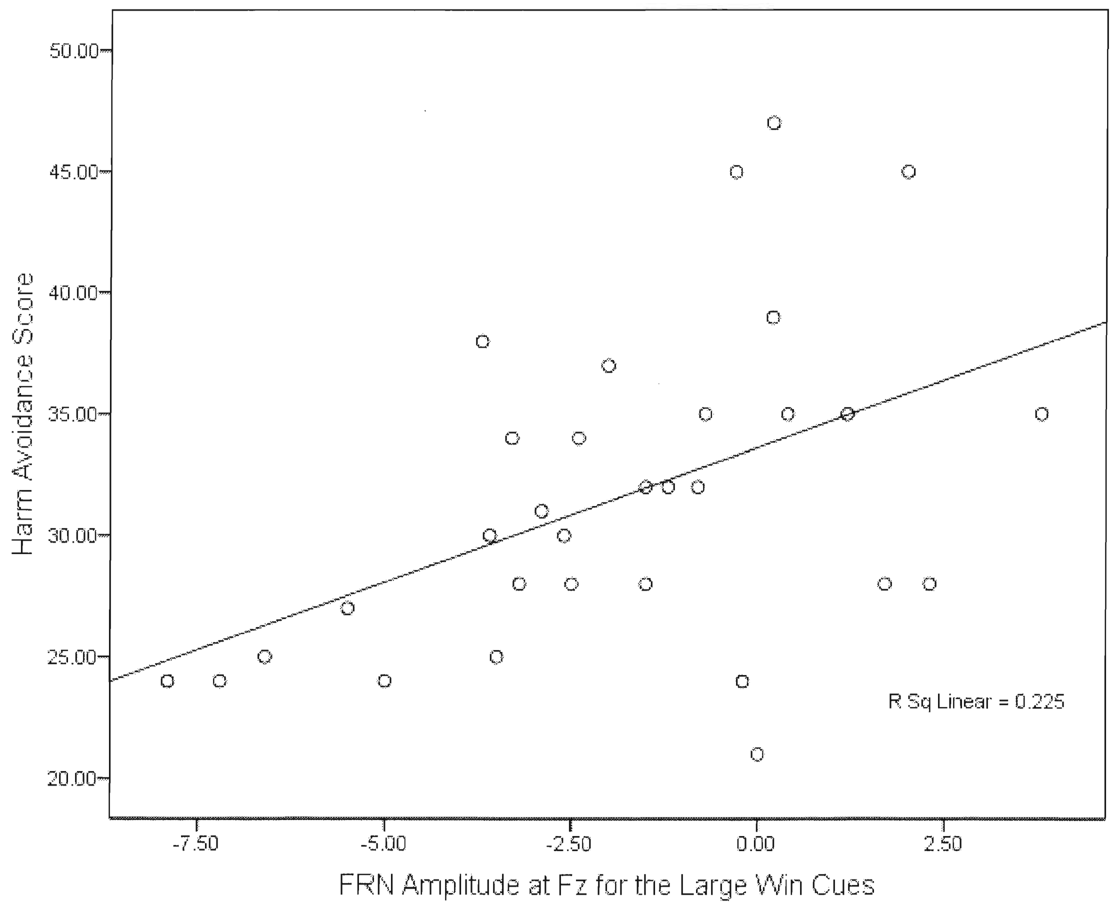


Figure 3.17

Scatter plots for the MFN amplitude at Fz during the small loss cues and sensation seeking scores.

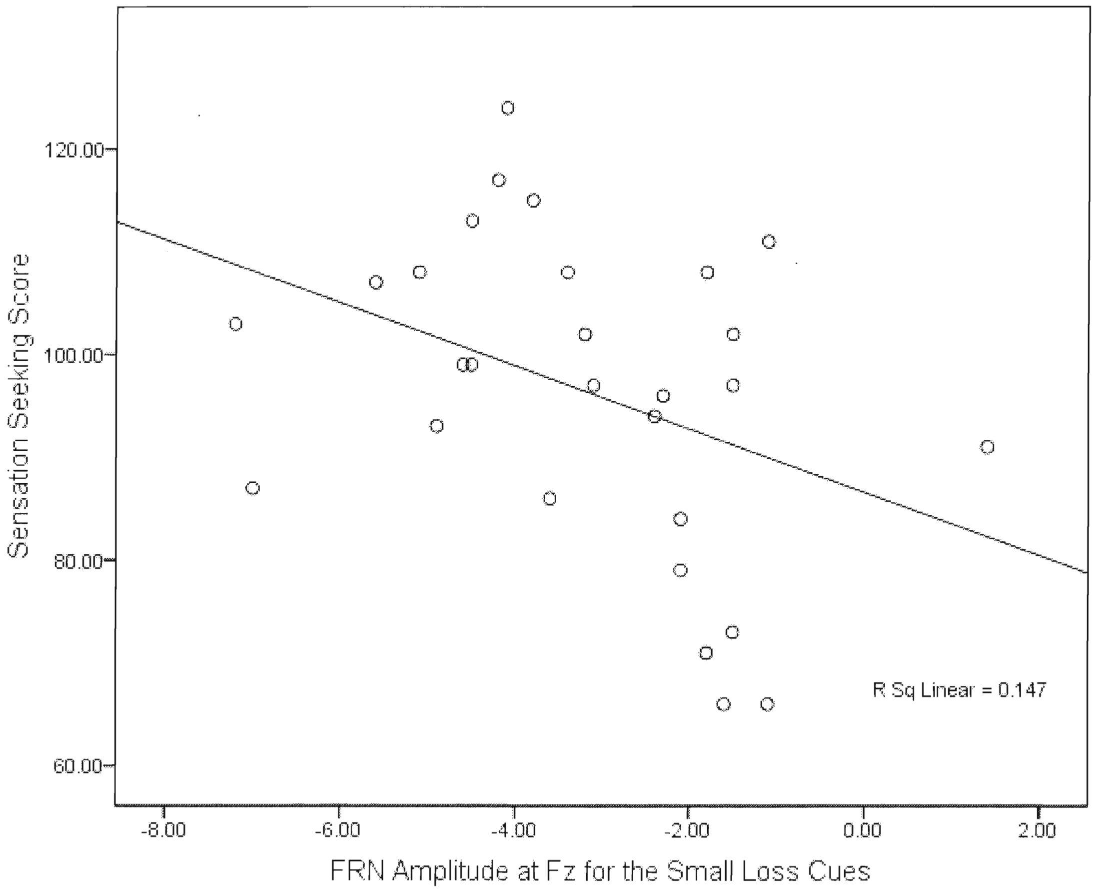


Figure 3.18

Scatter plots for the MFN amplitude at Fz during the large win cues and sensation seeking scores.

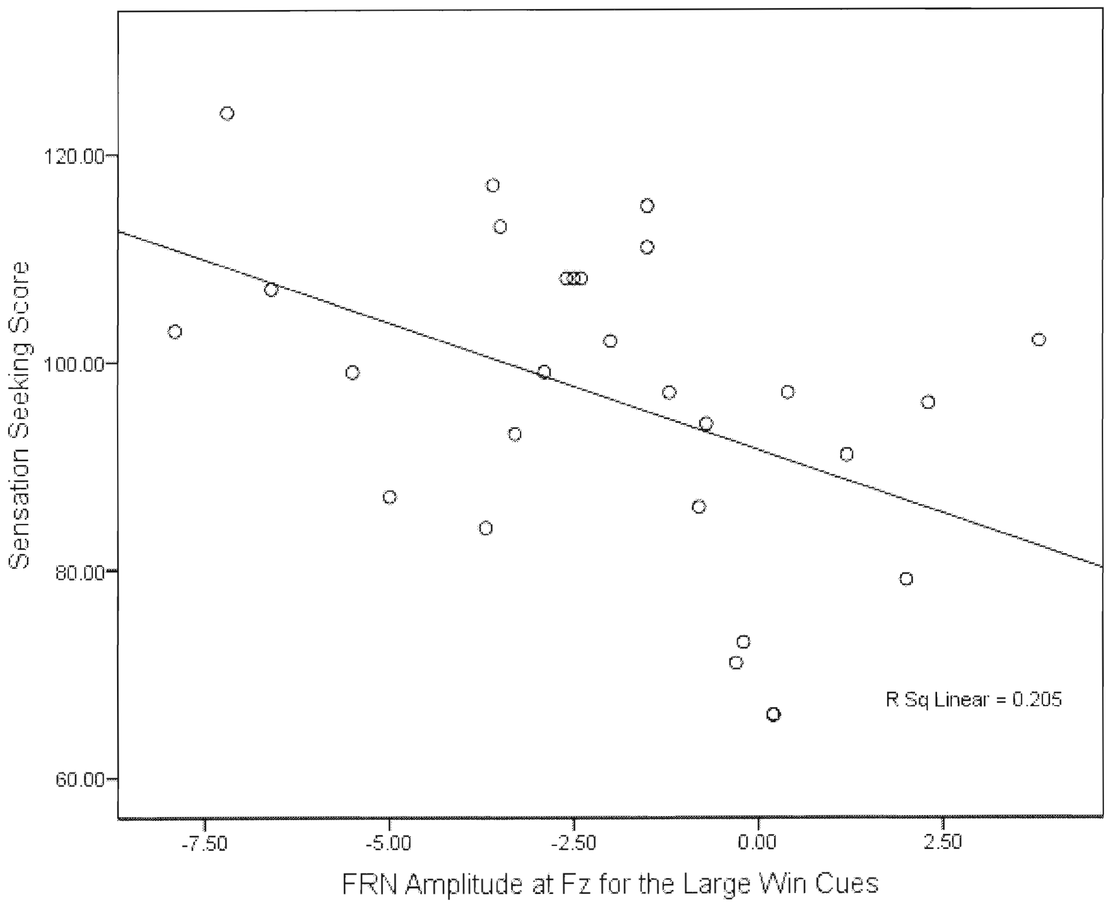


Figure 3.19

Scatter plots for the MFN amplitude at Fz during the large win cues and levels of reported cognitive distortions

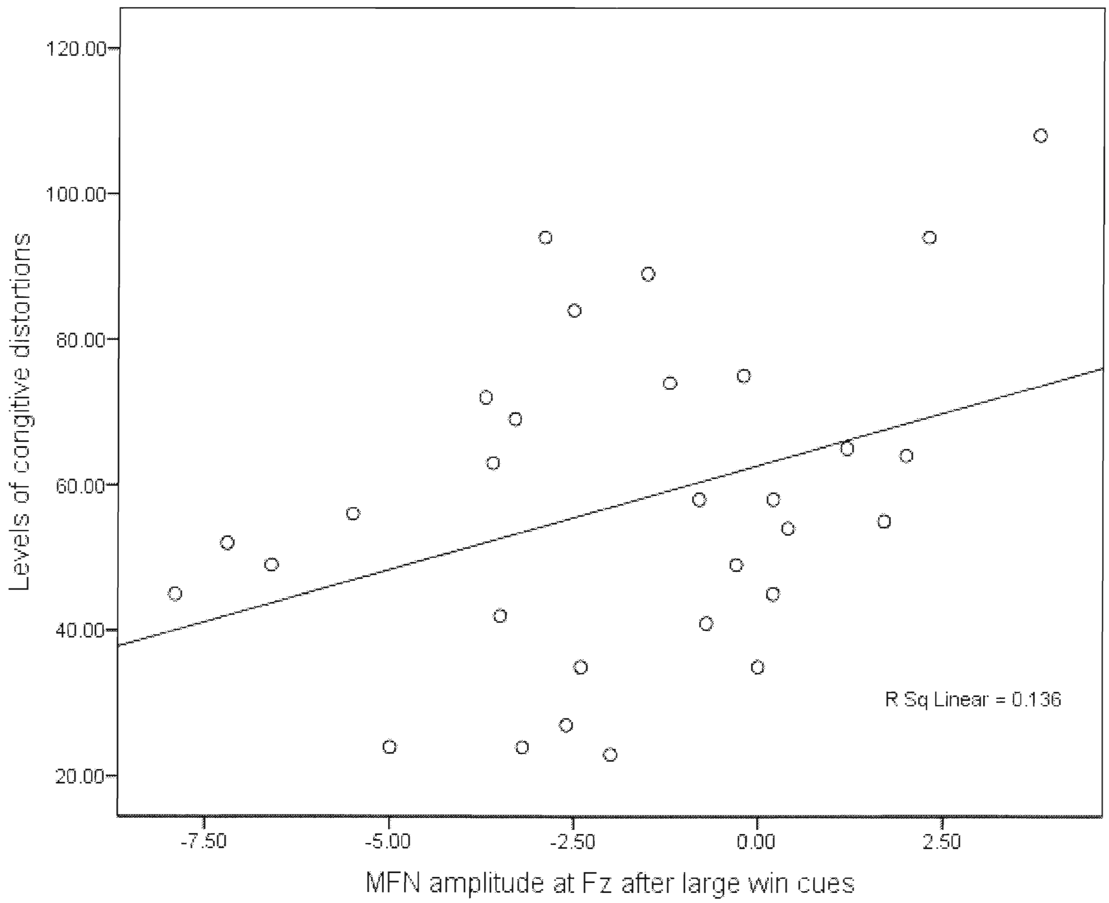


Figure 3.20

Scatter plots for the P3 amplitude at CPz during the small loss cues and harm avoidance scores

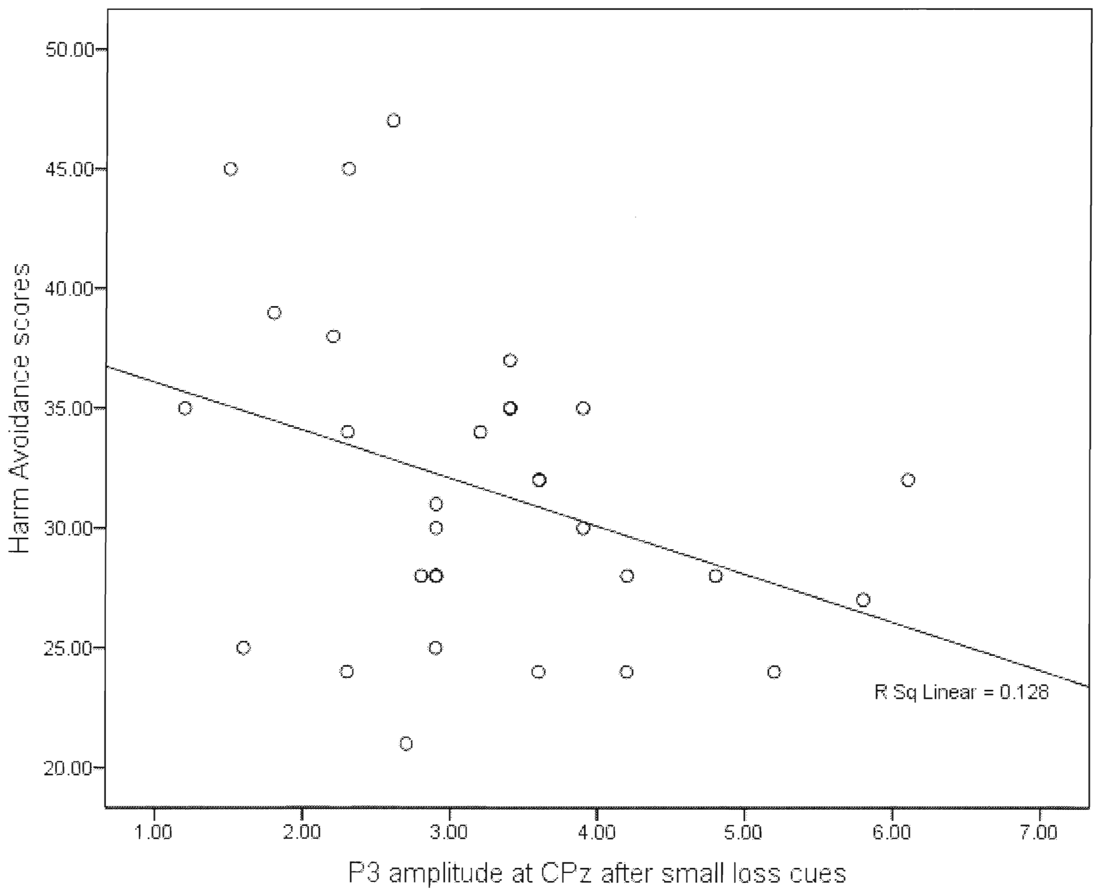


Figure 3.21

Scatter plots for the P300 amplitude at CPz during the small loss cues and sensation seeking scores.

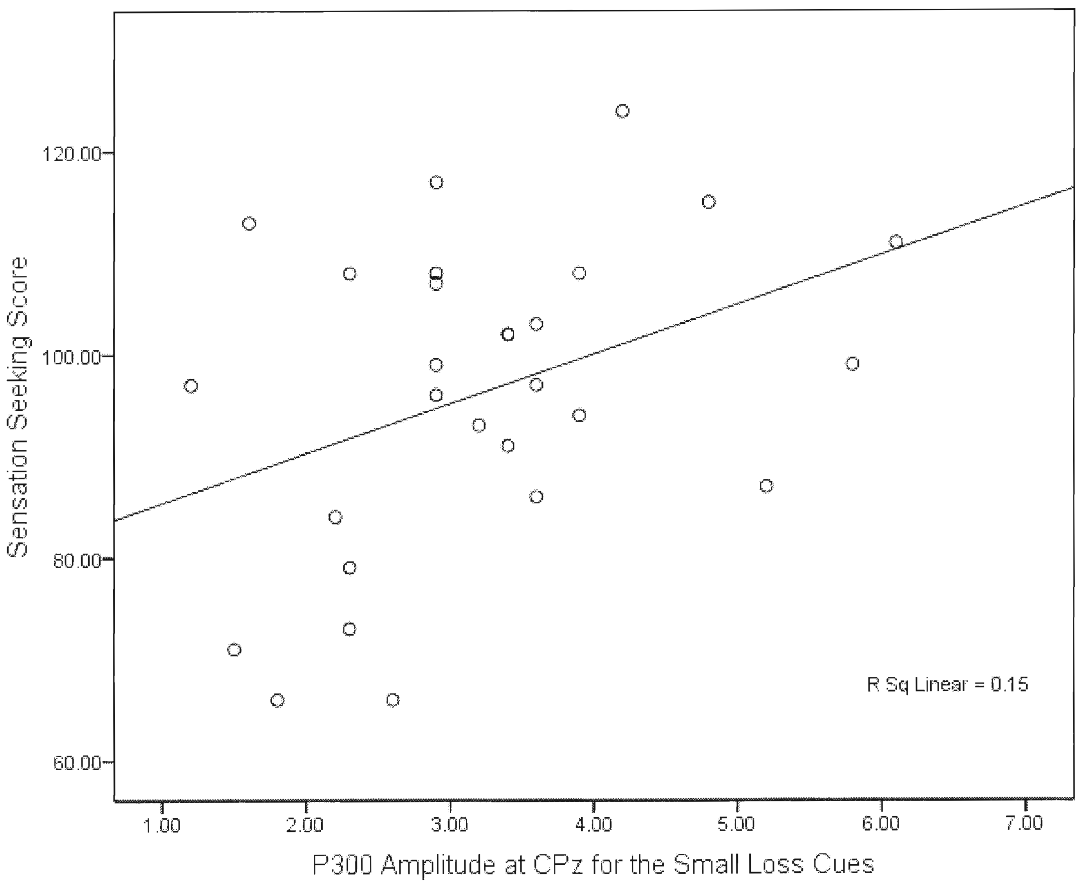


Figure 3.22

Scatter plots for the MFN amplitude at Fz during the zero cues and levels of cognitive distortions.

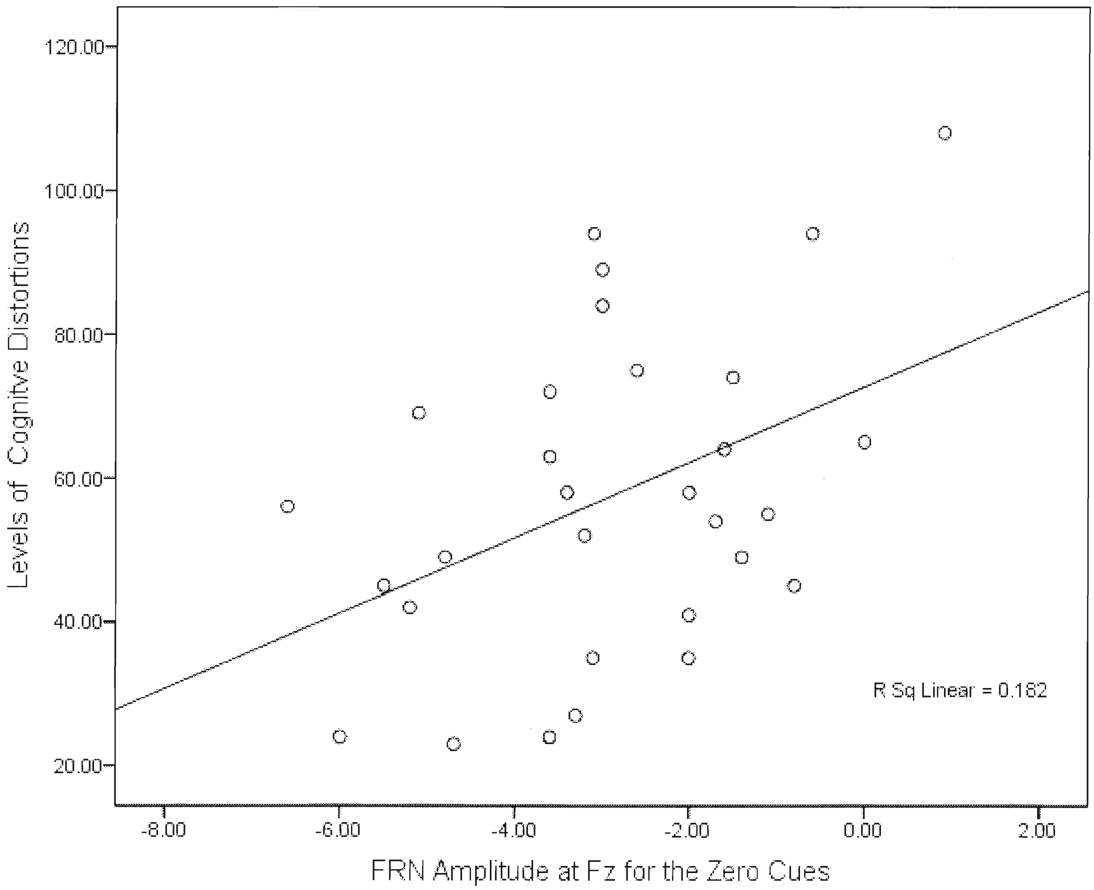


Figure 3.23

Scatter plots for the MFN amplitude at Fz during the zero cues and harm avoidance scores.

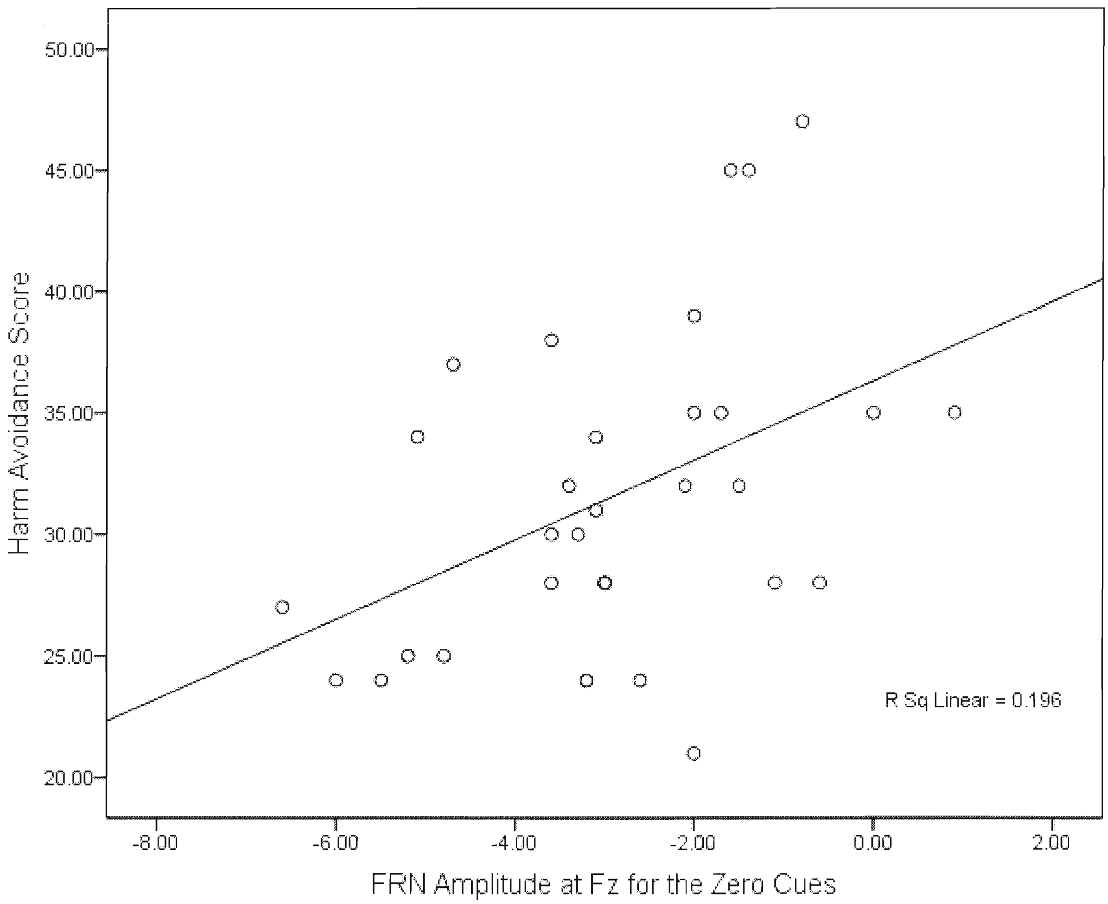
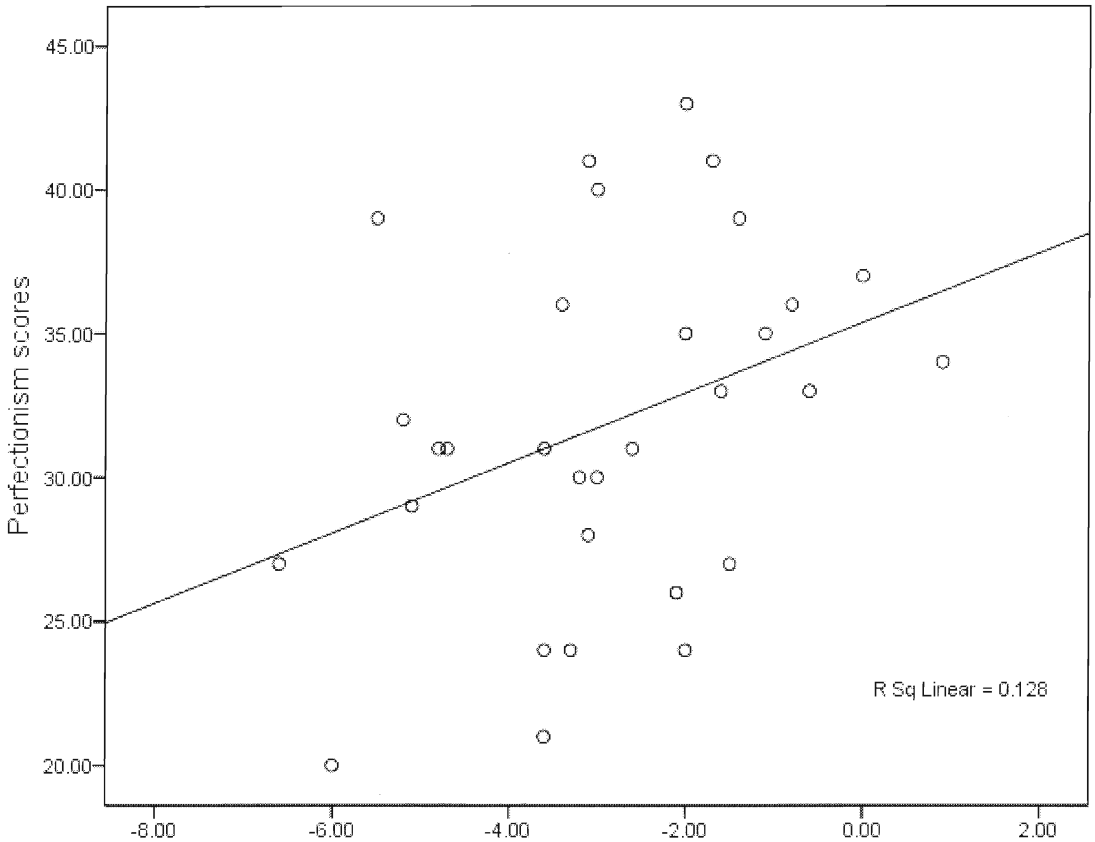


Figure 3.24

Scatter plots for the MFN amplitude at Fz during the zero cues and perfectionism scores.



MFN amplitude at Fz for the zero cue

Figure 3.25

Scatter plots for the P300 amplitude at CPz during the zero cues and scores on the BIS scale.

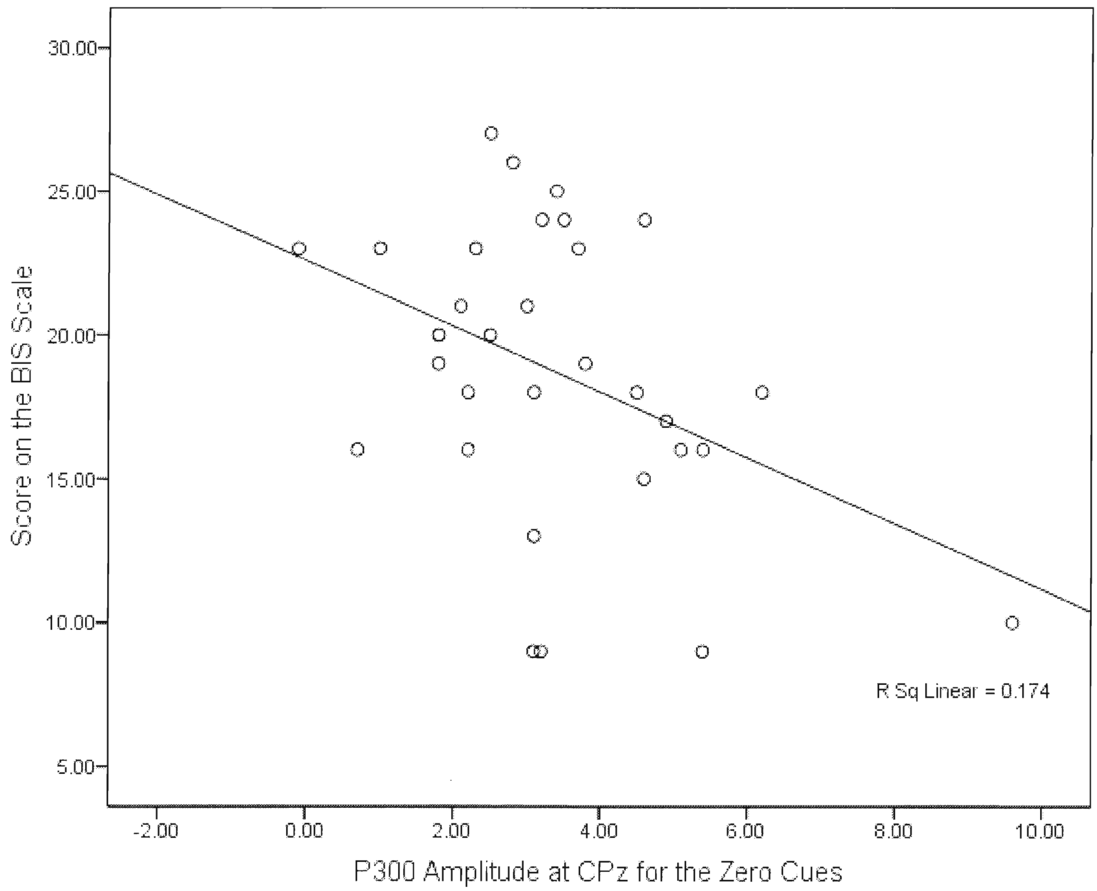


Figure 3.26

Scatter plots for the P300 amplitude at CPz during the zero cues and scores on the delay discounting task.

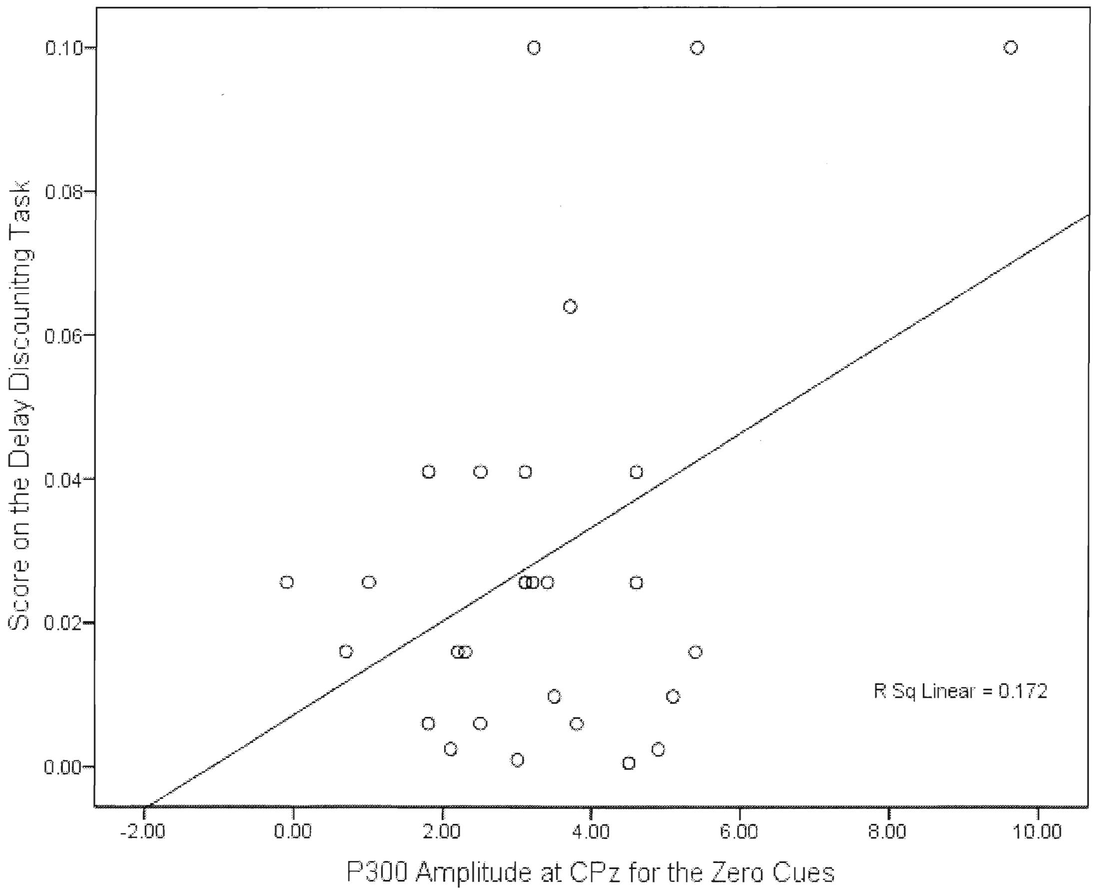


Figure 3.27

Scatter plots for the FRN amplitude at Cz during the win feedback and harm avoidance scores.

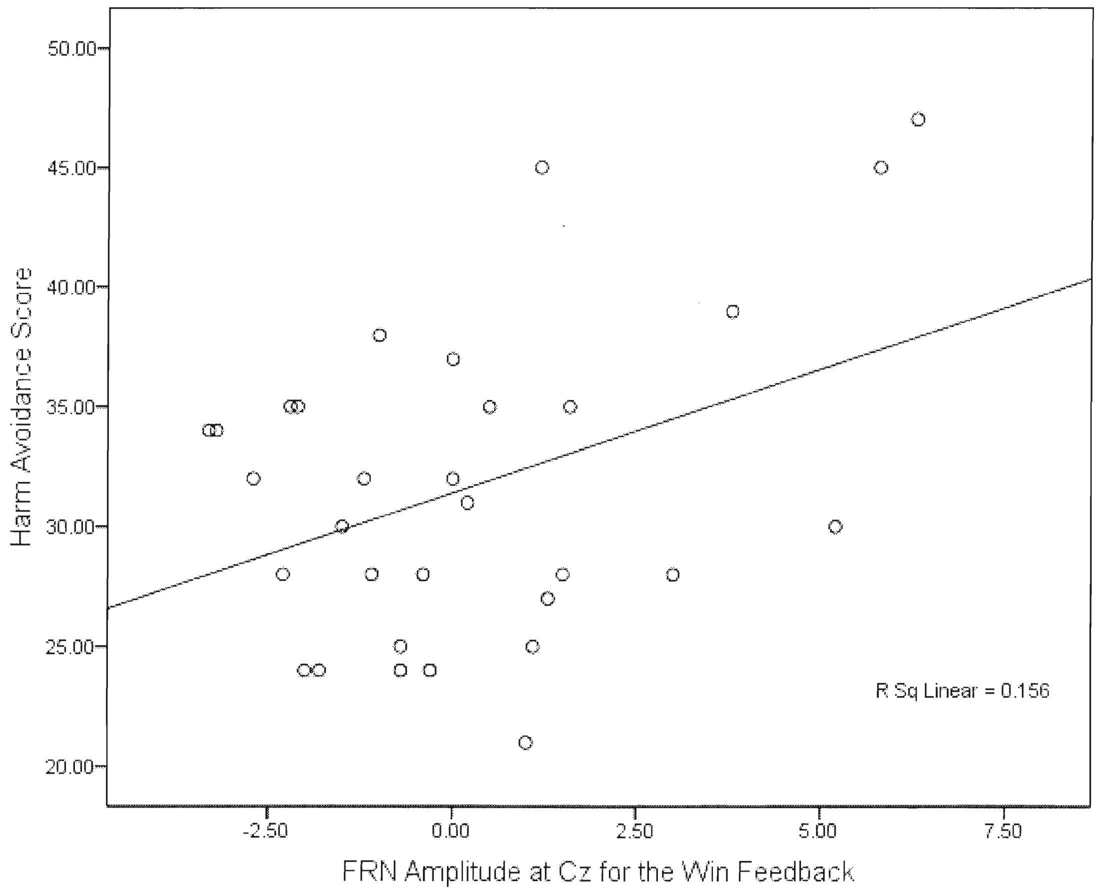


Figure 3.28

Scatter plots for the FRN amplitude at Cz during the loss feedback and harm avoidance scores.

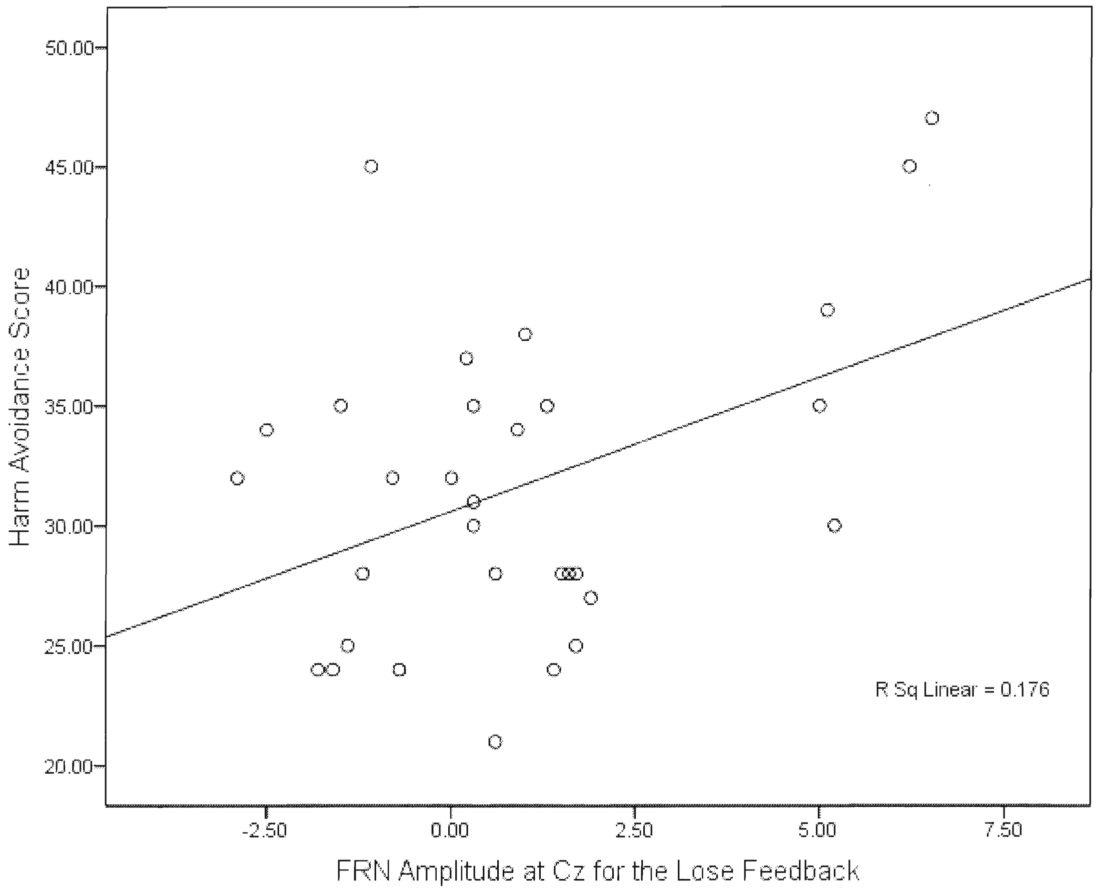


Figure 3.29

Scatter plots for the FRN amplitude at Cz during the loss feedback and sensation seeking scores.

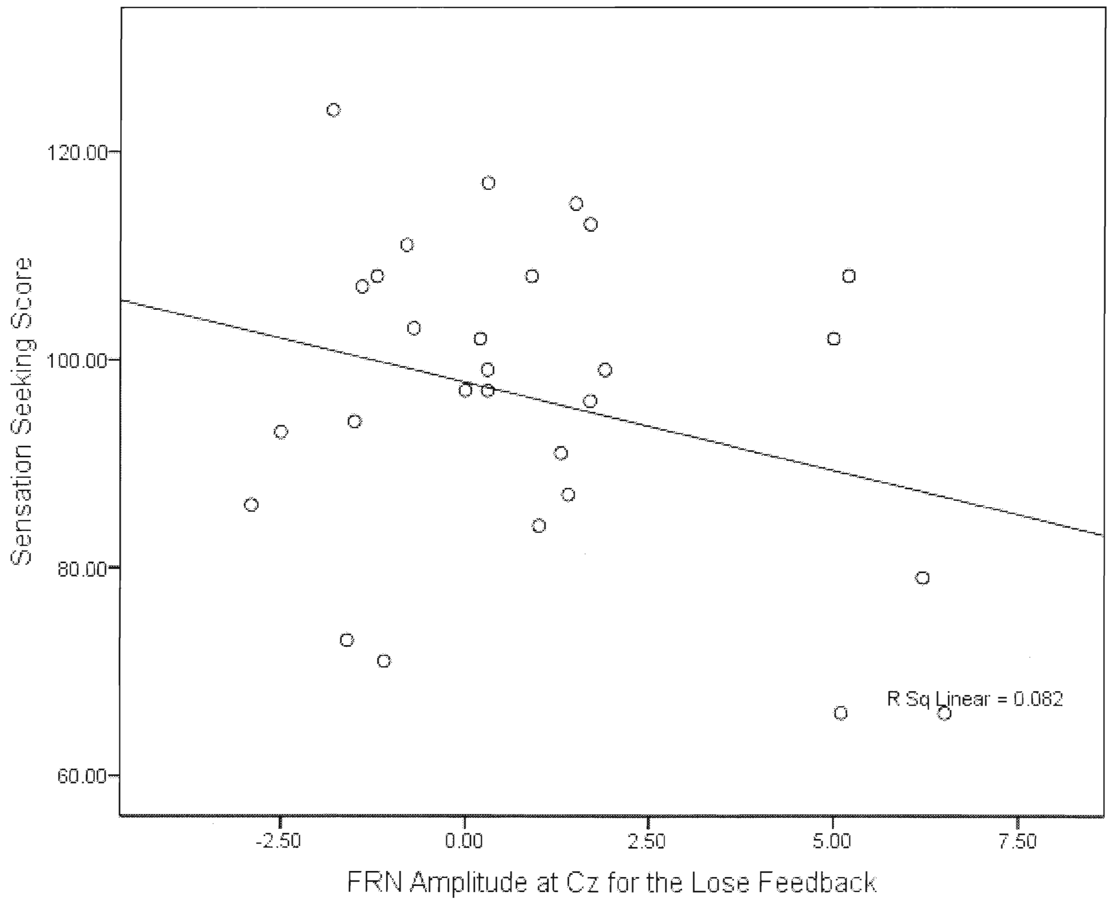


Figure 3.30

Scatter plots for the P300 amplitude at Cz during the win feedback and harm avoidance scores.

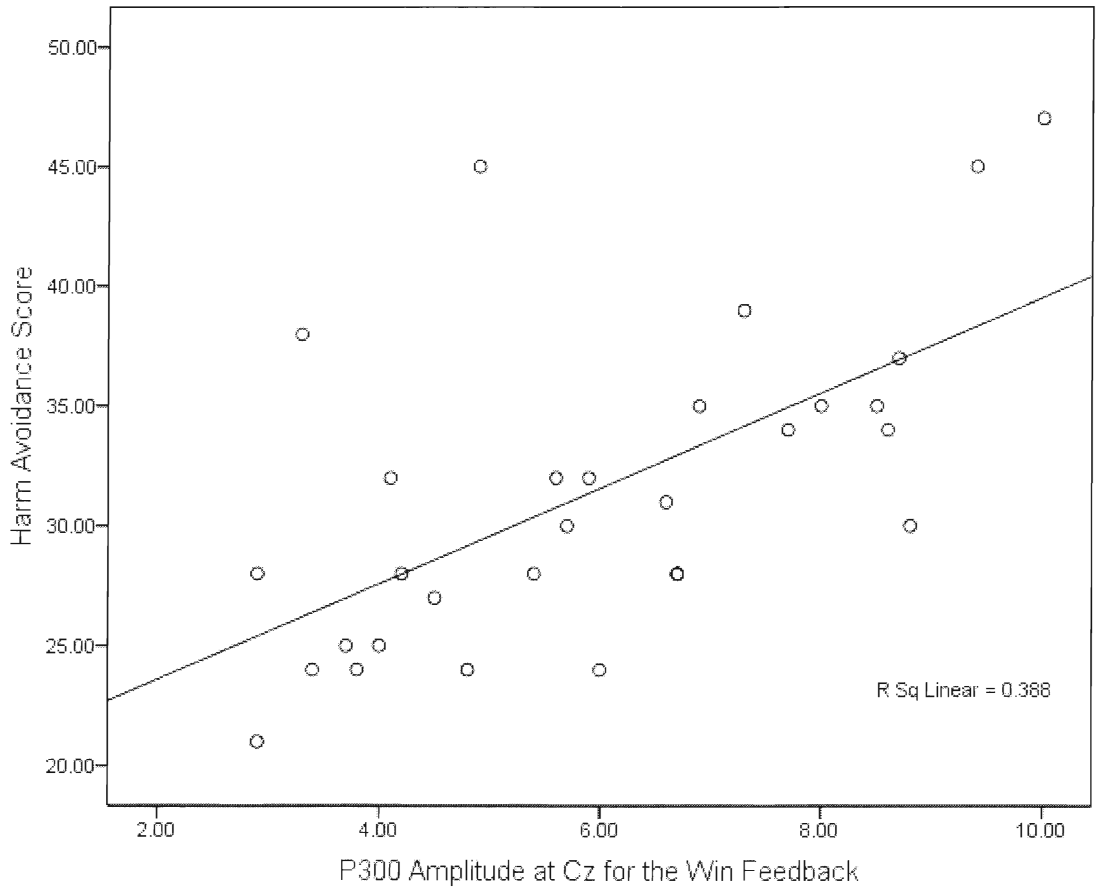


Figure 3.31

Scatter plots for the P300 amplitude at Cz during the loss feedback and harm avoidance scores.

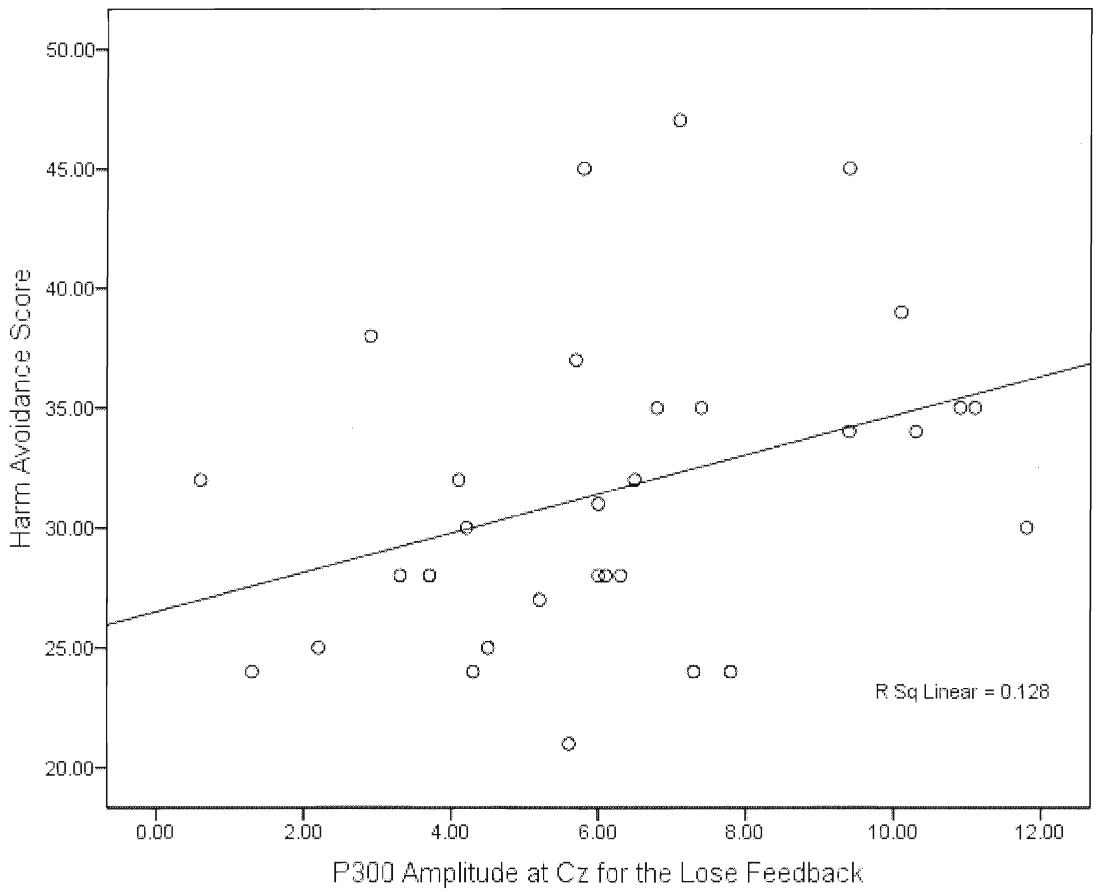
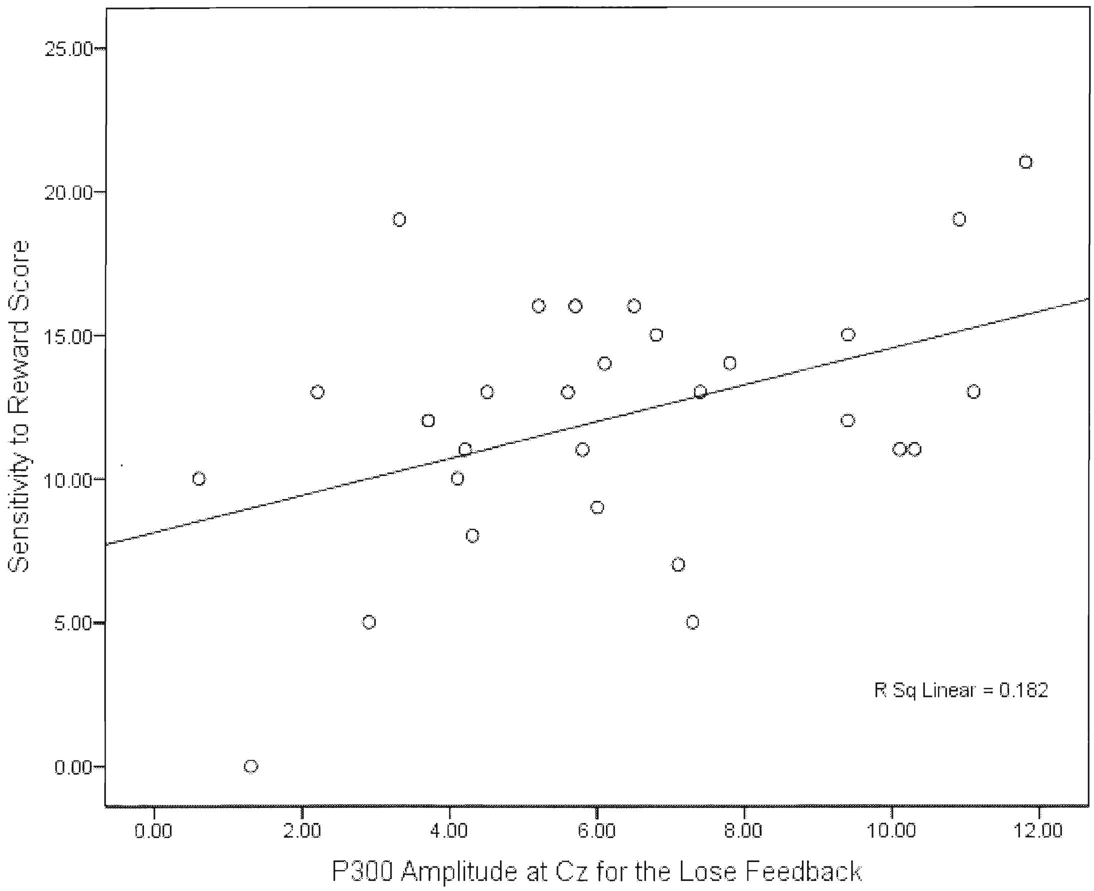


Figure 3.32

Scatter plots for the P300 amplitude at Cz during the loss feedback and sensitivity to reward scores.



Appendix A

Subject ID ___________________ Date: __________________

1. How old are you?_______________________ What is your major?_______________________

2. Sex: M F What are your goals after the completion of your current degree?_______________________

3. Have you ever been diagnosed/experienced any neurological conditions (e.g. epilepsy, stroke, concussion etc)?
____

4. Do you smoke cigarettes? Y N
If yes, approximately how many a day? _____________________________________

5. Have you experienced any recent stressor (e.g. death in the family, birth of a child, etc)?_______________________

6. For each of these activities, please decide which hand you normally use but checking the box. In each case, imagine that you are actually carrying out the activity before answering.

	1 Always Left	2 Usually Left	3 Either Hand	4 Usually Right	5 Always Right	6 Not Sure
1. Which hand do you use to write?	☐	☐	☐	☐	☐	☐
2. Which hand is used to throw a ball?	☐	☐	☐	☐	☐	☐
3. Which hand is used to draw?	☐	☐	☐	☐	☐	☐
4. Which hand is used to cut with a knife?	☐	☐	☐	☐	☐	☐
5. Which hand is used to hold a tennis racquet?	☐	☐	☐	☐	☐	☐
6. Hammer in a nail, which hand wields the hammer?	☐	☐	☐	☐	☐	☐
7. Which hand uses scissors?	☐	☐	☐	☐	☐	☐
8. Which hand strikes a match?	☐	☐	☐	☐	☐	☐
9. Thread a needle, which hand moves?	☐	☐	☐	☐	☐	☐
10. Which hand deals the cards?	☐	☐	☐	☐	☐	☐

BIS/BAS Scales

Listed below are items concerning behaviours exhibited by adults. Read each item carefully and decide how accurately the behaviour describes you. Indicate your response for each item by circling the number that corresponds to your response choice.

0= VERY ACCURATE
1= ACCURATE
2= NEITHER ACCURATE NOR INACCURATE
3= INACCURATE
4= VERY INACCURATE

1. If I think something unpleasant is going to happen I usually get pretty "worked up".
   0 1 2 3 4
2. I worry about making mistakes.
   0 1 2 3 4
3. Criticism or scolding hurts me quite a bit.
   0 1 2 3 4
4. I feel pretty worried or upset when I think or know somebody is angry at me.
   0 1 2 3 4
5. Even if something bad is about to happen to me, I rarely experience fear or nervousness.
   0 1 2 3 4
6. I feel worried when I think I have done poorly at something.
   0 1 2 3 4
7. I have very few fears compared to my friends.
   0 1 2 3 4
8. When I get something I want, I feel excited and energized.
   0 1 2 3 4
9. When I am doing well at something, I love to keep at it.
   0 1 2 3 4
10. When good things happen to me, it affects me strongly.
   0 1 2 3 4
11. It would excite me to win a contest.
   0 1 2 3 4
12. When I see an opportunity for something I like, I get excited right away.
   0 1 2 3 4
13. When I want something, I usually go all-out to get it.
   0 1 2 3 4
14.I go out of my way to get things I want.
   0 1 2 3 4
15. If I see a chance to get something I want, I move on it right away.
   0 1 2 3 4
16. When I go after something I use a "no holds barred" approach.
   0 1 2 3 4
17.I will often do things for no other reason than that they might be fun.
   0 1 2 3 4
18. I crave excitement and new sensations
   0 1 2 3 4
19. I am always willing to try something new if I think it will be fun.
   0 1 2 3 4

20. I often act on spur of the moment.

0	1	2	3	4

Neuroticism

On the following pages, there are phrases describing people's behaviors. Please use the rating scale below to describe how accurately each statement describes ***you.*** Describe yourself as you generally are now, not as you wish to be in the future. Describe yourself as you honestly see yourself, in relation to other people you know of the same sex as you are, and roughly your same age. So that you can describe yourself in an honest manner, your responses will be kept in absolute confidence. Please read each statement carefully, and then circle the number on the scale that relates to you.

Response Options
1=Very Inaccurate
2=Moderately Inaccurate
3=Neither Inaccurate nor Accurate
4=Moderately Accurate
5=Very Accurate

1. I often feel blue.
   1 2 3 4 5
2. I rarely lose my composure.
   1 2 3 4 5
3. I dislike myself.
   1 2 3 4 5
4. I remain calm under pressure.
   1 2 3 4 5
5. I am often down in the dumps.
   1 2 3 4 5
6. I have frequent mood swings.
   1 2 3 4 5
7. I am not easily frustrated.
   1 2 3 4 5
8. I panic easily.
   1 2 3 4 5
9. I seldom get mad.
   1 2 3 4 5
10. I am filled with doubts about things.
    1 2 3 4 5
11. I feel threatened easily.
    1 2 3 4 5
12. I am relaxed most of the time.
    1 2 3 4 5
13. I get stressed out easily.
    1 2 3 4 5
14. I am very pleased with myself.
    1 2 3 4 5
15. I fear for the worst.
    1 2 3 4 5
16. I am not easily bothered by things.
    1 2 3 4 5

17. I worry about things.
    1 2 3 4 5
18. I rarely get irritated.
    1 2 3 4 5
19. I seldom feel blue.
    1 2 3 4 5
20. I feel comfortable with myself.
    1 2 3 4 5

Perfectionism

On the following pages, there are phrases describing people's behaviors. Please use the rating scale below to describe how accurately each statement describes *you.* Describe yourself as you generally are now, not as you wish to be in the future. Describe yourself as you honestly see yourself, in relation to other people you know of the same sex as you are, and roughly your same age. So that you can describe yourself in an honest manner, your responses will be kept in absolute confidence. Please read each statement carefully, and then circle the number on the scale that relates to you.

Response Options

1 = Very Inaccurate
2 = Moderately Inaccurate
3 = Neither Inaccurate nor Accurate
4 = Moderately Accurate
5 = Very Accurate

1. I continue until everything is perfect.
   1 2 3 4 5

2. I am not bothered by messy people.
   1 2 3 4 5

3. I want every detail taken care of.
   1 2 3 4 5

4. I am not bothered by disorder.
   1 2 3 4 5

5. I want everything to be "just right"
   1 2 3 4 5

6. I want things to proceed according to plan.
   1 2 3 4 5

7. I demand perfection in others.
   1 2 3 4 5

8. I keep a sharp eye on others' work.
   1 2 3 4 5

9. I expect dedicated work from others.
   1 2 3 4 5

Conscientiousness

On the following pages, there are phrases describing people's behaviors. Please use the rating scale below to describe how accurately each statement describes *you.* Describe yourself as you generally are now, not as you wish to be in the future. Describe yourself as you honestly see yourself, in relation to other people you know of the same sex as you are, and roughly your same age. So that you can describe yourself in an honest manner, your responses will be kept in absolute confidence. Please read each statement carefully, and then circle the number on the scale that relates to you.

Response Options
1 = Very Inaccurate
2 = Moderately Inaccurate
3 = Neither Inaccurate nor Accurate
4 = Moderately Accurate
5 = Very Accurate

1. I am always prepared.
   1 2 3 4 5
2. I need a push to get started.
   1 2 3 4 5
3. I pay attention to details.
   1 2 3 4 5
4. I make a mess of things
   1 2 3 4 5
5. I get chores done right away.
   1 2 3 4 5
6. I don't put my mind on the task at hand
   1 2 3 4 5
7. I carry out my plans.
   1 2 3 4 5
8. I leave things unfinished.
   1 2 3 4 5
9. I make plans and stick to them.
   1 2 3 4 5
10. I mess things up.
    1 2 3 4 5
11. I complete tasks successfully.
    1 2 3 4 5
12. I shirk my duties.
    1 2 3 4 5
13. I do things according to a plan.
    1 2 3 4 5
14. I don't see things through.
    1 2 3 4 5
15. I am exacting in my work.
    1 2 3 4 5
16. I do just enough work to get by.
    1 2 3 4 5

17. I finish what I start.
    1 2 3 4 5
18. I find it difficult to get down to work
    1 2 3 4 5
19. I follow through with my plans.
    1 2 3 4 5
20. I waste my time.
    1 2 3 4 5

Obsessive Compulsive Characteristics

The following statements refer to experiences that many people have in their everyday lives. Circle the number that best describes **HOW MUCH** that experience has **DISTRESSED or BOTHERED you during the PAST MONTH.** The numbers refer to the following verbal labels:

0	1	2	3	4
Not at all	**A little**	**Moderately**	**A lot**	**Extremely**

1. I have saved up so many things that they get in the way.
   0 1 2 3 4
2. I check things more often than necessary.
   0 1 2 3 4
3. I get upset if objects are not arranged properly.
   0 1 2 3 4
4. I feel compelled to count while I am doing things.
   0 1 2 3 4
5. I find it difficult to touch an object when I know it has been touched by strangers or certain people.
   0 1 2 3 4
6. I find it difficult to control my own thoughts.
   0 1 2 3 4
7. I collect things I don't need.
   0 1 2 3 4
8. I repeatedly check doors, windows, drawers etc.
   0 1 2 3 4
9. I get upset if others change the way I have arranged things.
   0 1 2 3 4
10. I feel I have to repeat certain numbers.
    0 1 2 3 4
11. I sometimes have to wash or clean myself simply because I feel contaminated.
    0 1 2 3 4
12. I am upset by unpleasant thoughts and come into my mind against my will.
    0 1 2 3 4
13. I avoid throwing things away because I am afraid I might need them later even though I know I won't.
    0 1 2 3 4
14. I repeatedly check gas and water taps and light switches after turning them off.
    0 1 2 3 4
15. I need things to be arranged in a particular order.
    0 1 2 3 4
16. I feel that there are good and bad numbers.
    0 1 2 3 4
17. I wash my hands more often and longer than necessary.
    0 1 2 3 4
18. I frequently get nasty thoughts and have difficulty in getting rid of them.
    0 1 2 3 4

Sensitivity to Punishment/Sensitivity to Reward

Read the statement carefully and decide which of the 4 responses choices below most accurately describes your answer to the question. **Circle** the appropriate answer. Each statement can be answered with **ONE** of the following 4 responses:

YY = <u>very much Yes</u>, Y = <u>Yes</u>, N = <u>No</u>, NN = <u>very much No</u>

1. Do you often refrain from doing something because you are afraid of it being illegal?
   YY Y N NN

2. Does the good prospect of obtaining money motivate you strongly to do things?
   YY Y N NN

3. Do you prefer not to ask for something when you are not sure you will get it?
   YY Y N NN

4. Are you frequently encouraged to act by the possibility of being valued in your work?
   YY Y N NN

5. Are you often afraid of new or unexpected situations?
   YY Y N NN

6. Do you often meet people that you find physically attractive?
   YY Y N NN

7. Is it difficult for you to telephone someone you do not know?
   YY Y N NN

8. Do you like to take some drugs because of the pleasure you get from them?
   YY Y N NN

9. Do you often give up your rights when you know you can avoid a quarrel with a person?
   YY Y N NN

10. Do you often do things to be praised?
    YY Y N NN

11. As a child, were you troubled by punishments at home or in school?
    YY Y N NN

12. Do you like being the center of attention at a party or social meeting?
    YY Y N NN

13. In tasks that you are not prepared for, do you attach great importance to the possibility of failure?
YY Y N NN

14. Do you spend a lot of your time on obtaining a good image?
YY Y N NN

15. Are you easily discouraged in difficult situations?
YY Y N NN

16. Do you need people to show their affection for you all the time?
YY Y N NN

17. Are you a shy person?
YY Y N NN

18. When you are in a group, do you try to make your opinions the most intelligent or funniest?
YY Y N NN

19. Whenever possible, do you avoid demonstrating your skills for fear of being embarrassed?
YY Y N NN

20. Do you often take the opportunity to pick up people you find attractive?
YY Y N NN

21. When you are with a group, do you have difficulties selecting a good topic to talk about?
YY Y N NN

22. As a child, did you do a lot of things to get peoples' approval?
YY Y N NN

23. Is it often difficult for you to fall asleep when you think about things you have done or must do?
YY Y N NN

24. Does the possibility of social advancement ("moving up the social ladder") make you do things, even if it involves not playing fair?
YY Y N NN

25. Do you think a lot before complaining in a restaurant if your meal is not well prepared?
YY Y N NN

26. Do you prefer activities that have an immediate gain?
YY Y N NN

27. Would you be bothered if you had to return to a store if you were given the wrong change?
YY Y N NN

28. Do you often have trouble resisting the temptation of doing forbidden things?
YY Y N NN

29. Whenever you can, do you avoid going to unknown places?
YY Y N NN

30. Do you like to compete and do everything you can to win?
YY Y N NN

31. Are you often worried by things that you said or did?
YY Y N NN

32. Is it easy for you to associate tastes and smells to very pleasant events?
YY Y N NN

33. Would it be difficult for you to ask your boss for a raise (salary increase)?
YY Y N NN

34. Are there a large number of objects or sensations that remind you of pleasant things?
YY Y N NN

35. Do you generally try to avoid speaking in public?
YY Y N NN

36. When you start to play with a slot machine, is it often difficult for you to stop?
YY Y N NN

37. Do you, on a regular basis, think that you could do more things if it was not for you insecurity or fear?
YY Y N NN

38. Do you do things for quick gains?
YY Y N NN

39. Comparing yourself to people you know, are you afraid of many things?
YY Y N NN

40. Does you attention easily stray from work in the presence of an attractive stranger?
YY Y N NN

41. Do you often find yourself worrying about things so much that it disrupts your thinking?
YY Y N NN

42. Are you interested in money to the point of being able to do risky jobs?
YY Y N NN

43. Do you avoid doing things you like in order not to be rejected or disapproved?
YY Y N NN

44. Do you make most activities competitive?
YY Y N NN

45. Generally, do you pay more attention to threats than to pleasant events?
YY Y N NN

46. Would you like to be a socially powerful person?
YY Y N NN

47. Do you often refrain from doing something because of your fear of being embarrassed?
YY Y N NN

48. Do you like displaying your physical abilities even though this may involve danger?
YY Y N NN

Harm Avoidance

Directions: On the following pages, there are phrases describing people's behaviors. Please use the rating scale below to describe how accurately each statement describes *you.* Describe yourself as you generally are now, not as you wish to be in the future. Describe yourself as you honestly see yourself, in relation to other people you know of the same sex as you are, and roughly your same age. So that you can describe yourself in an honest manner, your responses will be kept in absolute confidence. Please read each statement carefully, and then circle the number on the scale that relates to you.

Response Options
1 = Very Inaccurate
2 = Moderately Inaccurate
3 = Neither Inaccurate nor Accurate
4 = Moderately Accurate
5 = Very Accurate

1. I would never go hang gliding or bungee jumping.
1 2 3 4 5

2. I take risks
1 2 3 4 5

3. I seek danger.
1 2 3 4 5

4. I am willing to try anything once.
1 2 3 4 5

5. I would never make a high risk investment.
1 2 3 4 5

6. I enjoy being reckless.
1 2 3 4 5

7. I do dangerous things.
1 2 3 4 5

8. I know no limits.
1 2 3 4 5

9. I avoid dangerous situations.
1 2 3 4 5

10. I let myself go.
1 2 3 4 5

Sensation Seeking (SS-F III)

Each statement can be answered **True** or **False**. Read the statement and decide which of the 4 responses choices below most accurately describes you. **Circle** the appropriate answer.

TT = very much true, T=true, F=false, FF=very much false

1. I often wish I could be a mountain climber.
   TT T F FF
2. I like some of the earthy body smells.
   TT T F FF
3. I can't stand watching a movie that I've seen before.
   TT T F FF
4. I like wild "uninhibited" parties.
   TT T F FF
5. I like to explore a strange city or section of town myself, even if it means getting lost.
   TT T F FF
6. I get bored seeing the same old faces.
   TT T F FF
7. I sometimes like to do things that are a little frightening.
   TT T F FF
8. People should dress in individual ways even if the effects are sometimes strange.
   TT T F FF
9. I would like to take off on a trip with no pre-planned or definite routes or timetables.
   TT T F FF
10. I get very restless if I have to stay around home for any length of times.
    TT T F FF
11. I have no patience with dull or boring persons.
    TT T F FF
12. I would like to learn to fly an airplane.
    TT T F FF
13. I would like to meet some persons who are homosexual (men or women).
    TT T F FF
14. When you can predict almost everything a person will do and say, he or she must be a bore.
    TT T F FF
15. I often like to get high (drinking liquor or smoking marijuana).
    TT T F FF

16. I would like to go scuba diving.

TT T F FF

17. I have tried marijuana or would like to.

TT T F FF

18. I usually don't enjoy a movie or play where I can predict what will happen in advance.

TT T F FF

19. I could conceive of myself seeking pleasures around the world with the "jet set".

TT T F FF

20. I would like to try some of the new drugs that produce hallucination.

TT T F FF

21. I would like to take up the sport of water skiing.

TT T F FF

22. I like to try new foods that I have never tasted before.

TT T F FF

23. I enjoy watching many of the "sexy" scenes in movies.

TT T F FF

24. The worst social sin is to be a bore.

TT T F FF

25. I often find beauty in the "clashing" of colours and irregular form of modern painting.

TT T F FF

26. I think I would enjoy the sensations of skiing very fast down a high mountain slope.

TT T F FF

27. I would like to try parachute jumping.

TT T F FF

28. Looking at someone's home movies or travel slides bores me tremendously.

TT T F FF

29. Keeping the drinks full is the key to a good party.

TT T F FF

30. I would like to sail a long distance in a small but seaworthy sailing craft.

TT T F FF

31. I would like to make friends in some of the "far-out" groups like artists or "hippies".

TT T F FF

32. I feel best after taking a couple of drinks.

TT T F FF

33. I would like to try surfboard riding.

TT T F FF

34. I enjoy the company of real “swingers”.

TT T F FF

35. I like people who are sharp and witty even if they do sometimes insult others.

TT T F FF

36. I like to have new and exciting experiences and sensations even it they are a little unconventional or illegal.

TT T F FF

37. I like to dive off the high board.

TT T F FF

38. A person should have considerable sexual experience before marriage.

TT T F FF

39. I prefer friends who are excitingly unpredictable.

TT T F FF

40. I like to date people who are physically exciting.

TT T F FF

Delay Discounting

Please take these choices seriously, as if they were real money choices.

Please circle the amount you would prefer in each case:

1. $54 today	OR	$55 in 117 days?
2. $55 today	OR	$75 in 61 days?
3. $19 today	OR	$25 in 53 days?
4. $31 today	OR	$85 in 7 days?
5. $14 today	OR	$25 in 19 days?
6. $47 today	OR	$50 in 160 days?
7. $15 today	OR	$35 in 13 days?
8. $25 today	OR	$60 in 14 days?
9. $78 today	OR	$80 in 162 days?
10. $40 today	OR	$55 in 62 days?
11. $11 today	OR	$30 in 7 days?
12. $67 today	OR	$75 in 119 days?
13. $34 today	OR	$35 in 186 days?
14. $27 today	OR	$50 in 21 days?
15. $69 today	OR	$85 in 91 days?
16. $49 today	OR	$60 in 89 days?
17. $80 today	OR	$85 in 157 days?
18. $24 today	OR	$35 in 29 days?
19. $33 today	OR	$80 in 14 days?
20. $28 today	OR	$30 in 179 days?
21. $34 today	OR	$50 in 30 days?
22. $25 today	OR	$30 in 80 days?
23. $41 today	OR	$75 in 20 days?
24. $54 today	OR	$60 in 111 days?
25. $54 today	OR	$80 in 30 days?
26. $22 today	OR	$25 in 136 days?
27. 20 today	OR	$55 in 7 days?

Cognitive Distortions (Gambler's Beliefs Questionnaire)

Read each of the following statements carefully. Rate to what extent you agree or disagree with each statement by *circling* a number.

1	2	3	4	5	6	7
Strongly agree			**Neutral**			**Strongly Disagree**

1. I think of gambling as a challenge.

   1 2 3 4 5 6 7

2. My knowledge and skill in gambling contribute to the likelihood that I will make money.

   1 2 3 4 5 6 7

3. My choices or actions affect the game on which I am betting.

   1 2 3 4 5 6 7

4. If I am gambling and losing, I should continue because I don't want to miss a win.

   1 2 3 4 5 6 7

5. I should keep track of previous winning bets so that I can figure out how I should bet in the future.

   1 2 3 4 5 6 7

6. When I am gambling, "near misses" or times when I almost win remind me that if I keep playing I will win.

   1 2 3 4 5 6 7

7. Gambling is more than just luck.

   1 2 3 4 5 6 7

8. My gambling wins are evidence that I have skill and knowledge related to gambling.

   1 2 3 4 5 6 7

9. I have a "lucky" technique that I use when I gamble.

   1 2 3 4 5 6 7

10. In the long run, I will win more money than I will lose gambling.

    1 2 3 4 5 6 7

11. Even though I may be losing with my gambling strategy or plan, I must maintain that strategy or plan because I know it will eventually come through for me.

    1 2 3 4 5 6 7

12. There are certain things I do when I am betting (for example, tapping a certain number of times, holding a lucky coin in my hand, crossing my fingers, etc.) which increase the chances that I will win.

1 2 3 4 5 6 7

13. If I lose money gambling, I should try to win it back.

1 2 3 4 5 6 7

14. Those who don't gamble much don't understand that gambling success requires dedication and a willingness to invest some money.

1 2 3 4 5 6 7

15. Where I get money to gamble doesn't matter because I will win and pay it back.

1 2 3 4 5 6 7

16. I am pretty accurate at predicting when a "win" will occur.

1 2 3 4 5 6 7

17. Gambling is the best way for me to experience excitement.

1 2 3 4 5 6 7

18. If I continue to gamble, it will eventually pay off and I will make money.

1 2 3 4 5 6 7

19. I have more skills and knowledge related to gambling than most people who gamble.

1 2 3 4 5 6 7

20. When I lose at gambling, my losses are not as bad if I don't tell my loved ones.

1 2 3 4 5 6 7

21. I should keep the same bet even when it hasn't come up lately because it is bound to win.

1 2 3 4 5 6 7

Appendix B

Date: ____________

Project Title: **Brainwave Responses to Winning Money**

Principal Investigator:
Angela Dzyundzyak, MA Candidate
Department of **Psychology**
Brock University
905-688-5550 x3034, ad03cr@brocku.ca

Faculty Supervisor:
S.J. Segalowitz, Professor
Department of **Psychology**
Brock University
(905) 688-5550 Ext. **3465,** ssegalowitz@brocku.ca

INVITATION

You are invited to participate in a study that involves research. The purpose of this study is to measure brain activity while performing a gambling task as well as examine personal style and an individual's experiences relate to the brain patterns.

WHAT'S INVOLVED

As a participant, you will be asked to answer some questionnaires assessing activity preferences and experience in participating in gambling behaviours. Then a brainwave sensor net will be placed on your scalp. You will be asked to complete some tasks on the computer. The first task will require you to respond within the allotted time in order to win or avoid losing a certain monetary reward. During the second task you will be asked to choose between two cards showing the amount of possible win/loss. Once the decision is made you will be given feedback if it was a win or a loss and what the alternate outcome would have been. Tasks will be divided into 9 and 5 blocks respectively, 5 minutes per each block. After each block the running total will be recorded and at the end of the experiment a block number for each task will be drawn at random. The amount accumulated during that trial will be given as a monetary reward. Once the computer tasks are finished, the sensors will be removed. Participation will take approximately 3 hours of your time.

POTENTIAL BENEFITS AND RISKS

Possible benefits of participation include the chance to see your brain activity on a computer screen, and ask questions of the researchers about EEG procedures and brain health. There are no known or anticipated risks associated with participation in this study.

CONFIDENTIALITY

All information you provide is considered confidential; your name will not be included or, in any other way, associated with the data collected in the study. Furthermore, because our interest is in the average responses of the entire group of participants, you will not be identified individually in any way in written reports of this research.

Data collected during this study will be kept for 5 years after final publication of results and stored in a limited access area of the Brock Neuropsychology laboratory. Only researchers associated with the Brock Neuropsychology laboratory will have access to the data.

VOLUNTARY PARTICIPATION

Participation in this study is voluntary. If you wish, you may decline to answer any questions or participate in any component of the study. Further, you may decide to withdraw from this study at any time and may do so without any penalty or loss of benefits to which you are entitled. Participation hours will be awarded at a rate of 0.5 research hour per half an hour to the nearest half hour. Monetary compensation will be based on the amount of money won at the point of withdrawal; the amount given will depend on the rules of the task completed prior to withdrawal.

PUBLICATION OF RESULTS

Results of this study may be published in professional journals and presented at conferences. Feedback about this study will be available through Angela Dzyundzyak (ad03cr@brocku.ca). As EEG data takes a long time to analyze, we do not anticipate full results of the study to be ready until April 2009.

CONTACT INFORMATION AND ETHICS CLEARANCE

If you have any questions about this study or require further information, please contact the Principal Investigator or the Faculty Supervisor using the contact information provided above. This study has been reviewed and received ethics clearance through the Research Ethics Board at Brock University (REB #07-217). If you have any comments or concerns about your rights as a research participant, please contact the Research Ethics Office at (905) 688-5550 Ext. 3035, reb@brocku.ca.

Thank you for your assistance in this project.

CONSENT FORM

I agree to participate in the study described above. I have made this decision based on the information I have read in the Information-Consent Letter. I have had the opportunity to receive any additional details I wanted about the study and understand that I may ask questions in the future. I understand that I may withdraw this consent at any time.

I am participating in this experiment for ____ hours of research participation in a psychology course as well as monetary reward ($20 to $40 on average).

______________________________ ______________________________

Signature of participant Course for participation

Signature of experimenter ______________________________

OR

I am participating in this experiment for a monetary reward only. This experiment will not count toward research participation hours in a psychology course.

______________________________ ______________________________

Signature of participant Signature of experimenter

Appendix C

Questions following the pure gambling task (Study 1)

Instructions: Indicate how happy/disappointed you felt in the following scenarios.

1. Please indicate how HAPPY you were when you WON a SMALL amount (~\$0.50)?
2. Please indicate how HAPPY you were when you WON a LARGE amount (~\$2.00)?
3. Please indicate how DISAPPOINTED you were when you LOST a SMALL amount (~\$0.50)?
4. Please indicate how DISAPPOINTED you were when you LOST a LARGE amount (~\$2.00)?

Instructions: Assuming the card you CHOSE was a WIN please answer the following questions.

5. (Chose Win) Please indicate how HAPPY you were when the alternative was a SMALLER win ?
6. (Chose Win) Please indicate how DISAPPOINTED you were when the alternative was a LARGER win?
7. (Chose Win) Please indicate how HAPPY you were when the alternative was a LOSS ?

Instructions: Assuming the card you CHOSE was a LOSS please answer the following questions.

8. (Chose Loss) Please indicate how HAPPY you were when the alternative was a LARGER loss ?
9. Chose Loss) Please indicate how DISAPPOINTED you were when the alternative was a SMALLER loss?
10. (Chose Loss) Please indicate how DISAPPOINTED you were when the alternative was a WIN?

Appendix D

Feedback Form – Neuropsychology Lab -- Brock University

Title of Study: **Brainwave Responses to Winning Money**

Dear Participant,

Thank you for taking part in this study. Without the help of volunteers these types of studies could not be done.

As you are aware, this research study was conducted by Angela Dzyundzyak, in the Psychology Department of Brock University. The purpose of the study was to pilot the tasks involving winning and losing money and identify any event related potentials (ERPs) that are associated with various stages of processing of reward-related information (e.g. large or small) as well as feedback information (win vs. loss).

The first task that you have completed was adapted from paper by Bjork and colleagues (2004). Originally this task was used to investigate activations of various brain areas using fMRI. We are hoping to employ the modified task in order to define ERPs specifically related to differentiation between the value of the reward and positive vs. negative feedback. Additionally, employing similar task will not only allow us to compare the obtained results with previous research but aid in localization of the obtained ERPs based on the fMRI data. The second task was also adapted from a previous study done in 2004 by Yeung and Sanfey. These authors showed that value (small vs. large) and valence (win vs. loss) of the reward are processed separately in the brain. In this study, we will try to replicate their findings with a slightly modified task. Developing relatively short and straightforward tasks that allow us to separate responses and processes that comprise risk-taking behaviour is necessary in order to move the field forward and will later allow researchers to employ these tasks to examine other populations (e.g. adolescents at risk for gambling problems).

The win and loss rate for both tasks were artificially manipulated for research purposes and thus do not indicate success at gambling. The first task sped up in case of win and slowed down after losses. The second paradigm had a success rate of 60% and 40% loss.

In addition to piloting the tasks, this study examined the role individual differences play in the risk-taking behaviour. The questionnaires that you have completed were designed to measure levels of various individual differences in personality traits such as sensation-seeking, harm-avoidance and impulsivity. These data will later be used to examine the extent to which individual differences contribute/related to risk-taking behaviour. As you are aware all the data will be kept strictly confidential and thus during the scoring of the questionnaires you will not be identified in any way.

If you would like to learn more about the results of this study you could call Angela Dzyundzyak at the 905-688-5550, Ext. 3034, or email her at ad03cr@brocku.ca. It takes a lot of time to do the analyses though so the results are not likely to be ready before September 2009; however, if you are interested in the results feel free to leave your email and we will let you know when the results are available.

If you have any concerns or would like to find out more about gambling-related issues the Niagara Alcohol and Drug Assessment Services (NADAS) website is a good resource (http://www.nadas.on.ca/). Additionally, NADAS (24-hour on call service: 905-684-1859) as well as the Student Development Center at Brock University (ext. 3240 or 5484) offer counselling services for individuals with gambling problems.

Thank you again for taking part. Your help was very much appreciated.

If you have any issues you would like to discuss regarding your involvement in the study, you could call the Brock Research Ethics Board through the Research Office at 905-688-5550, Ext. 3035.

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Copy of Research Ethics Board Acceptance Letter

February 25, 2008

FROM: Michelle McGinn, Chair Research Ethics Board (REB)
TO: Dr. Segalowitz, Psychology; Angela Dzyundzyak

FILE: 07-217 SEGALOWITZ/DZYUNDZYA
TITLE: Brainwave responses to winning money

The Brock University Research Ethics Board has reviewed the above research proposal.

DECISION: Accepted as Clarified
Please Note: The average amount and/or range of monetary compensation should be stated on the consent form.

This project has received ethics clearance for the period of February 25, 2008 to October 1, 2009 subject to full REB ratification at the Research Ethics Board's next scheduled meeting. The clearance period may be extended upon request. ***The study may now proceed.***

Please note that the Research Ethics Board (REB) requires that you adhere to the protocol as last reviewed and cleared by the REB. During the course of research no deviations from, or changes to, the protocol, recruitment, or consent form may be initiated without prior written clearance from the REB. The Board must provide clearance for any modifications before they can be implemented. If you wish to modify your research project, please refer to http://www.brocku.ca/researchservices/forms to complete the appropriate form Revision or Modification to an Ongoing Application.

Adverse or unexpected events must be reported to the REB as soon as possible with an indication of how these events affect, in the view of the Principal Investigator, the safety of the participants and the continuation of the protocol.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of any research protocols.

The Tri-Council Policy Statement requires that ongoing research be monitored. A Final Report is required for all projects upon completion of the project. Researchers with projects lasting more than one year are required to submit a Continuing Review Report annually. The Office of Research Services will contact you when this form *Continuing Review/Final Report* is required.

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